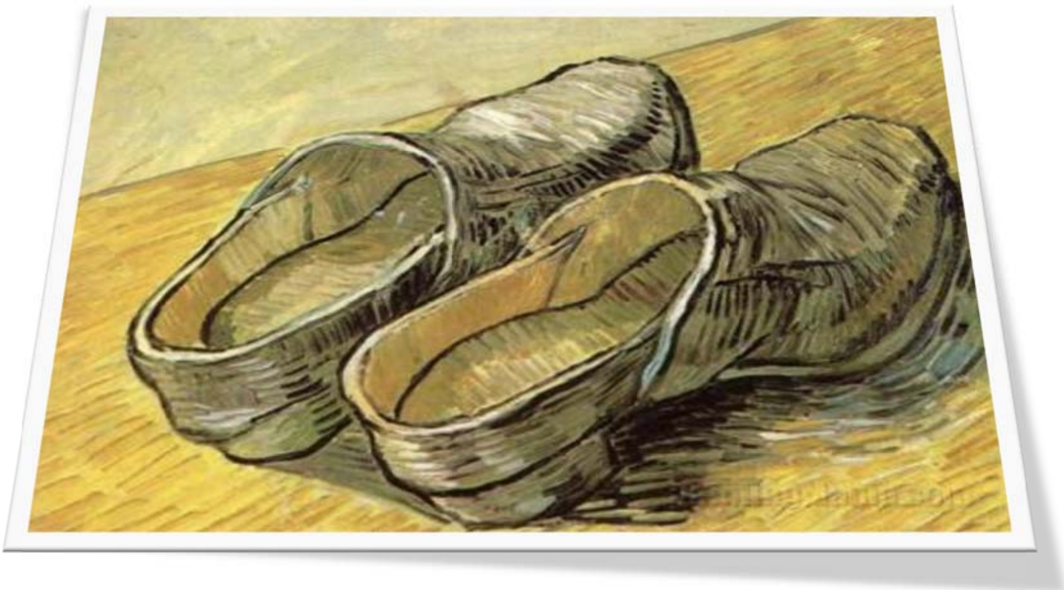
ARE THESE "CLOGS" MADE FOR WALKING?

Irene Vikatou



Osteochondritis Dissecans:

evidence of strenuous activity and trauma

on skeletal elements of the foot from a

post-medieval rural society in the Netherlands

Cover Picture:

A Pair of Leather Clogs, 1888

Vincent van Gogh (1853-1890)

Oil on Canvas, 32.5 X 40.5 cm

Van Gogh Museum, Amsterdam

“In Paris, Van Gogh had painted several pictures of workman’s boots. In Arles he painted this pair of leather clogs, the attributes of the peasant life with which he had once more begun to concern himself in these rural southern areas. The artist also knew still lifes featuring clogs from work by the peasant painter Millet, for whom he had great admiration. To Millet, clogs symbolized the poetry of peasant life.”

http://www.vangoghmuseum.nl/vgm/index.jsp?lang=en&page=2901

Irene Vikatou

S1222074

Supervisor:

Dr. Andrea Waters-Rist

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Irene Vikatou

Email: evicatos@hotmail.com

Contents

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1. Introduction

Time travelling has not yet been invented. Had it been, it would solve many unanswered questions about the past such as how did our ancestors live. What was daily life like? What types of activity did people engage in? Many believe that the dead take their secrets to the grave. This idea however, can be reversed to some extent. Reconstructing life in the past is the goal of archaeology. It is a challenge when reconstructions are based mostly on evidence from the material culture discovered at the site. It is useful to examine the remains of the people themselves, via their bones and teeth. Thorough examination of these remains can reveal valuable information about a persons' daily life. Sex and age-at-death, to start with, are two of the most significant things that can often be assessed by analyzing a skeleton (Buikstra and Ubelaker 1994). Sometimes, it is also possible to reconstruct, to a certain level, sociocultural variables of the past when grave goods accompanying the dead are retrieved.

Diseases, such as osteoarthritis (OA), that cause changes to bone can be recognized on recent as well as ancient skeletal remains. The same applies to bone lesions that result from intense every-day activity and that can be observed on certain parts of the skeleton. Advances in medicine over the past century have illuminated to a great extent the causes of bone modifications. Subsequently, knowledge from modern clinical research has proved to be an exceptionally useful tool in the analysis of archeological skeletal remains.

Quite often, we wonder how people lived in times when technology was not as advanced as it is today. How different is the modern way of living from that of the past? Today it is regarded that we live a more sedentary life than that of our ancestors. Could that be visible on our skeleton? Part of the answer could be given by examining a skeleton for a specific bone lesion, known as Osteochondritis Dissecans (OD), which many researchers correlate to trauma, either direct or repetitive microtrauma, resulting from vigorous activity (Detterline *et al.* 2008; Ortner 2003; Schindler 2007; Waldron 2009). Its high occurrence in athletes (Aichroth 1971) and especially throwing athletes and gymnasts (Baker III *et al.* 2010; Schenk Jr. *et al.* 1996; Wahegaonkar *et al.* 2007), suggests that it could be used to indicate equivalent types of strenuous activity when observed on archeological skeletal remains. Wells (1974) analyzed ancient skeletal material from the British Isles and observed that OD occurred more often in the Romano-British and Anglo-Saxon populations than in the people of the Bronze Age period. He suggests that the areas which the former groups inhabited were rather inhospitable and had to be cleared for agriculture. Doing so, using poor footwear and inefficient equipment, contributed to the development of OD due to trauma and other kind of injuries that are typical side-effects of intensive farming. Wells (1974) also notes that the low frequency of OD in the populations from the Bronze Age period could suggest pastoralism as their every-day activity.

The main purpose of this thesis is to examine the prevalence of OD in a post-Medieval population from the Netherlands in order to illuminate past activity behavior. Subsequently, a brief review of the etiology and basic characteristics of OD is presented in this chapter, to elucidate why OD can be used as an activity-related indicator.

1.1 Osteochondritis Dissecans

1.1.1 Definition

OD describes a pathological condition that affects the subchondral bone and surrounding cartilage of synovial joints, such as the knee, elbow, and ankle. Its main characteristic is the partial or complete detachment of articular cartilage, or both cartilage and subchondral bone, eventually leading to a loose-body formation within the joint cavity (fig.1) (Schindler 2007). The bone-cartilage fragment often remains unaltered but in some cases, it might continue growing and even remodel within the synovial fluid due to nutritional supply from the latter; thus changing size and shape. The area which the fragment detaches from may heal over time. The affected area starts remodeling and undergoes sclerosis (i.e. stiffening of the connective tissue) (Aufderheide and Martín-Rodríguez 1998). Also described as the "crater" (Solomon *et al.* 2010, 114), the lesion may be covered by a thin layer of bone, with its surface will always remain depressed (Aufderheide and Martín-Rodríguez 1998; Ortner 2003). Occasionally the loose-body, depending on the type and motion of the joint, could be resorbed into the area it was detached from or be embedded on the articular surface of the corresponding bones of the joint; therefore appearing as bump (George Maat personal communication).

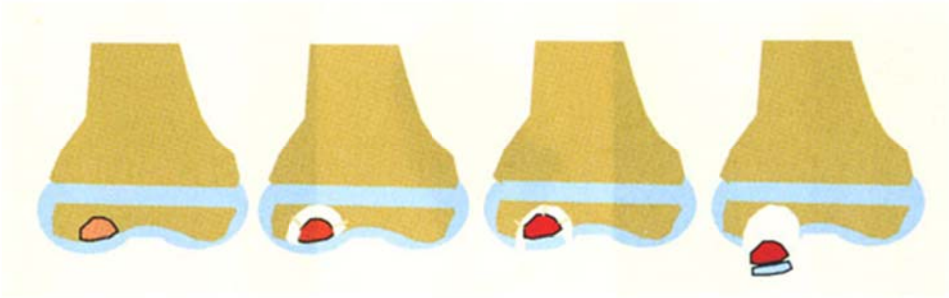

Figure 1: The stages of the formation of an OD lesion (after Staheli and Schwartz, 2003. Source: http://www.health-pic.com/EX/09-19-01/osteochondritis_dessicans.jpg,)

1.1.2 Historical Review and Terminology

Franz König, Professor of Surgery in Göttingen, was the first to introduce the term Osteochondritis Dissecans in 1887, thus also known in clinical literature as König's disease. The suffix "-itis" was used by König to indicate an inflammatory response to subchondral necrosis as the primary cause of the formation of these loose-bodies (Schindler 2007) and not primary arthritis or major trauma of the joint (Ytrehus *et al.* 2007). However, this term has been regarded as inappropriate and has been replaced by many scientists with the term "osteochondrosis" as it is generally agreed that the primary lesions are not characterized by inflammation (Schindler 2007; Ytrehus *et al.* 2007). Nevertheless, the term Osteochondritis Dissecans has prevailed and it is going to be used through the entire text of this thesis research.

1.1.3 Location

Osteochondritis Dissecans can develop on any synovial joint. The highest frequency is observed in the knee followed by the elbow, ankle, hip, shoulder and finally the wrist (Waldron 2009, 154). However this order varies, with other authors stating the talus as the second most commonly affected area, followed by the elbow (Aufderheide and Martín-Rodríguez 1998). According to clinical literature certain areas are more likely to be affected such as convex surfaces compared to concave ones (Waldron 2009). Nevertheless, many clinical cases exhibit OD lesions in typical concave areas such as the glenoid cavity (Gogus *et al.* 2008), the tarsal navicular bone (fig. 2) (Bui-Mansfield *et al.* 2000), and the distal end of the tibia (tibial plafond) (Bui-Mansfield *et al.* 2000)

Figure 2: OD on the proximal articular surface of the tarsal navicular bone. Bilateral occurrence. Middenbeemster Skeletal Collection, Leiden University

1.1.4 Etiology

There is no consensus regarding the etiology of osteochondritic lesions. Many factors have been suggested to play a role with trauma, either major, repetitive micro-trauma, or indirect, being a major cause (Schenk *et al.* 1996; Schindler 2007; Waldron 2009). Other theories include avascular necrosis of subchondral bone (Ytrehus *et al.* 2007), ischemia, accessory ossification centers within the epiphyses which leads to abnormal ossification, and even poor or mal-nutrition (Schindler 2007; Ytrehus *et al.* 2007). In some cases, members of the same family have developed the disease. This indicates that heredity should also be considered as a plausible factor (Stougaard 1964). Despite the frequent appearance of OD in athletes (Waldron 2009), which would support the repetitive trauma etiology, it is agreed by many researchers that a multifactoral aetiology is most appropriate (Schindler 2007; Ytrehus *et al.* 2007).

1.1.5 Epidemiology

Clinical studies demonstrate that OD can occur at any age. The onset age of OD in childhood and adolescence when patients' epiphyses are still open, is known as Juvenile Osteochondritis Dissecans (JOD). Adult OD describes the lesions occurring in patients with fully closed epiphyses (Schenk *et al.* 1996;

Schindler 2007). According to Aufderheide and Rodriguez-Martin (1998) the highest peak occurs in the age category of 10-25 years. Other studies demonstrate that OD occurs in even more advanced ages, for example, 33-49 years of age, OD of the tibial plafond (Bui-Mansfield *et al.* 2000), and even 60+ years of age, OD of Glenoid Cavity (Gogus and Ozturk, 2008).

Generally, OD is observed in males more than females (Aufderheide and Rodríguez-Martín 1998; Ortner 2003; Ponce 2010; Schenck Jr. *et al.* 1996; Solomon *et al.* 2010; Waldron 2009) regardless of the joint involved. This could be due to the fact that men generally engage in more strenuous activities, and tend to be more athletic (Ponce 2010) which consequently would imply a higher probability of trauma or repetitive micro-trauma, a factor with a high probability of causing OD lesions.

1.1.6 Classification

Aichroth (1971) examined 200 patients who suffered from OD of the knee and was able to develop a classification system for the distal end of the femur, which is still used today (fig. 3). In Aichroth's (1971) research, 69% of the cases of OD occurred on the lateral posterior site of the medial femoral condyle (MFC). Thus, this is described as the "classical OD" location. However, other areas of the knee could also be affected. The involvement of the central area of the MFC, extending to the intercondylar notch was found in six percent of cases and is described as "extended classical" location. The central, inferior location of either the medial or the lateral condyle was affected in 10-13% of the cases. This region suffers high pressure due to body weight; thus considered as the weight-bearing surface of the knee. Lesions occurring close to the intercondylar notch are rare. Finally, the anterior area of the femoral condyles does not appear to be affected in more than two percent of the cases described.

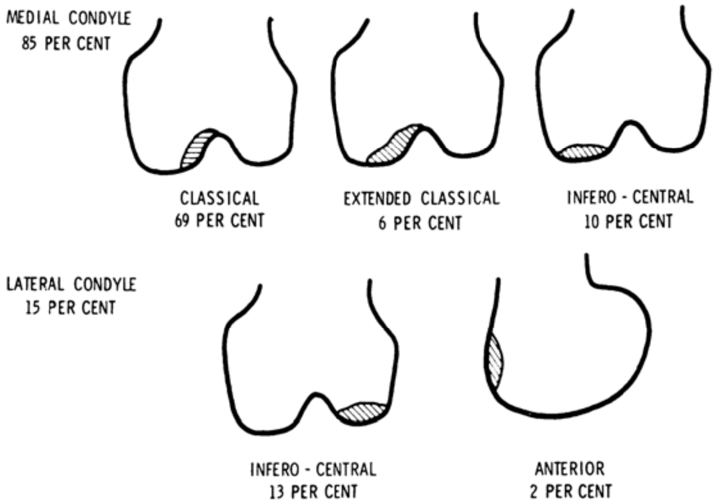

Figure 3: Common sites of Osteochondritis Dissecans in the distal femur (Aichroth 1971, 440)

Efforts at classifying OD locations of other joints, besides the knee, are scarce. This is probably due to the fact that most of the OD studies conducted on other joints refer to individual cases where only the location of the occurring lesion is described (Ponce 2010). For instance, the second metacarpal head (Lowyck and Smet 2008), the first metatarsophalangeal joint (Bojanić *et al.* 2011), the patella (Desai *et al.* 1987), the talus and the distal end of the tibia (Bauer *et al.* 1987), are some of these single case-reports.

Attempts have been made to develop a classification system according to the extent of the abnormality based on radiographic images from patients. The stages have an onset of intact cartilage, to detection of cartilage disruption, and finish with a separated cartilage-bone fragment, due to the inability of the tissue to heal and repair (Ponce 2010). But this system is not applicable to archeological skeletal elements because cartilage and tissue are not preserved.

Examining dry bone for osteochondritic lesions has a significant advantage over radiographic or medical scanning images since distinction of the different stages of the lesion is possible. Dastugue and Gervais (1992) cited by Aufderheide and Martín-Rodríguez (1998, 83) proposed a classification system where three phases can be observed:

"1. Necrotic phase: the sequestrum is not yet detached from the articular surface and is limited by a sharply defined border.

2. Exposition phase: the sequestrum is detached, exposing the crater in the underlying spongiosa.
3. Cicatrization phase: a layer of new bone lines the crater."

The main characteristic of osteochondritic lesions is that they are focal by nature. That does not however, exclude the possibility of more than one lesion occurring in the same individual. Usually they appear unilaterally (fig. 4) (Detterline *et al.* 2008) but they are often also observed bilaterally and symmetrically (fig. 5) (Detterline *et al.* 2008; Schindler 2007; Ytrehus *et al.* 2007).

Figure 4: OD of the posterior subtalar facet. Note the development of secondary OA Middenbeemster Skeletal Collection, Leiden University

Figure 5: OD of the head of the first metatarsal (MT1). Bilateral occurrence. Middenbeemster Skeletal Collection, Leiden University

1.1.7 Prevalence

Most OD reports come from individual cases and therefore population-based studies concerning the disease are few. Perhaps this is because it is considered a rare disorder with an occurrence of 15-30 out of 100,000 people (Gogus and Cagatay 2008). Additionally, there could be an underestimation of true occurrences due to the fact that the condition in early stages can be completely asymptomatic (Resnick and Goergen 2002). Bauer *et al.* (1987) did a 20 year follow-up study on OD of the ankle. They suggest that the frequency rate is under-diagnosed due to difficulties that arise with visual radiology and due to the possibility of cases of self-healing.

1.1.8 Paleopathology Cases

The vast majority of OD studies on dry bone involve cases of single or small numbers of individuals. Wells (1962b) reports a case of the lesion in a Late Saxon burial near Norwich. He also describes it in skeletons from the Romano-British period discovered at Cirencester, in skeletal material from the Anglo-Saxon period and also from the Bronze Age (Wells 1974). Loveland *et al.* (1987) report osteochondritic lesions of the femoral condyle in bones from Native Americans retrieved from three sites from the U.S.A. Plains area. An interesting case of bilateral OD is mentioned by During *et al.* (1994) in a skeleton recovered from the seventeenth century Swedish warship, VASA. Finally, one more interesting case comes from the medieval burial site of St. George's Cathedral in Cantebury, England. The disorder occurs on the right medial femoral condyle of a 14-year old individual and includes both the depression and loose body. The fragments' shape generally corresponds to the lesion but it is larger than the crater, thus indicating continued growth after its detachment (Ortner 2003, 353).

Unfortunately, the literature does not offer many cases of OD occurring in ancient populations. Martín-Oval and Rodríguez-Martín (1994), cited in Aufderheide and Martín-Rodríguez (1998, 83) report a high frequency among the ancient inhabitants of the Canary Islands. But according to two recent reports, one by Ponce (2010) among ancient inland agriculturists and fishermen in Chile, and the other by Bourbou (2010) on Byzantine skeletons from Crete, the frequency of occurrence is very small, being 0.6 % and 0.2% respectively.

Previous research on skeletal assemblages from the Netherlands was made for Alkmaar (Schats 2012) and for Dordrecht (Maat *et al.* 1998) and yielded OD results of 4.8% (8/165) and 3.5% (11/316), respectively. In Alkmaar, individuals were most commonly affected in the MT1 and the talus with three cases each; two individuals had OD of the hip and one in the third metacarpal. The report from Dordrecht only mentions the number of the affected individuals and not the bones it occurred in. Both collections date from the medieval period. Finally, it should be mentioned that in the retrieved skeletons from Alkmaar only 63 out of 165 individuals had both feet present, without however implying that all of the skeletal elements of each foot were retrieved in every case.

Birkett (1982) states that diagnosis of the disease should be made with caution in archeological bones since normal variations of the joint surfaces could be misinterpreted as OD lesions. Waldron (2009) agrees with the previous statement adding also that OD should not be confused with osteoarthritis (OA), a common long-term complication of the joints.

OA is actually quite easy to differentiate from OD with a naked eye. One of the features of OA that could be confused with OD, is a sub-chondral cyst. But the other features of OA are not similar in appearance to OD. Crenshaw (2006, 200) states that: "the major difference between OD and OA involve mineralization of tissues surrounding the joint and excessive mineralization of bone. The synovial membranes become calcified and surrounding tissues are invaded by calcified outgrowths (osteophytes). In OA bone the joint surfaces become hardened (sclerosis). The joint space is often reduced and bone surfaces become distorted".

Finally, it is important to note that taphonomic processes and post mortem damage to the bone could be mistaken for osteochondritic lesions (Loveland *et al.* 1984), something that would lead in an over-estimation of the disease. Taphonomy refers to the physical and chemical processes that an organism undergoes after its death as it is incorporated into geological deposits (Stodder 2008). Bone degradation can be the result of insect activity, ground water, and soil acidity leading to demineralization of the bone matrix. That can result in the emergence of porosity and pitting of the bone surface that could mimic true lesions observed in diseases such as OA and OD (Aufderheide and Rodríguez-Martín 1998). Depressions on the joint surfaces due to taphonomic processes can mimic the appearance of OD in shape and size, but their edges will appear sharp and usually irregular compared to OD, exhibits smooth edges indicative of healing. Consequently, misdiagnosis of lesions can be overcome by careful examination and consistency with developed classification criteria for a described disease.

1.2 Research Questions

The purpose of this thesis research is to determine the presence of Osteochondritis Dissecans in a skeletal sample from the mid-19th century from the Middenbeemster cemetery in the Netherlands. The population of that region is known to have been a rural society that mainly practiced agriculture, therefore suggesting a high amount of activity.

The first research question is to determine whether a predominately agricultural society exhibits a comparatively high frequency of OD lesions. This data will contribute to the debate regarding the role of activity in OD etiology. The second research question is to determine if there is variation in OD frequency between males and females and between different age groups in order to better understand sex or age-based differences in activity in this population. Finally the third goal of this research will be to determine whether one of the two sides holds a higher probability of been affected by OD, due the difference in dominance between right and left.

The Middembeenster skeletal collection offers a unique opportunity to study OD in a large population sample, compared to previous research. Apart from illumintating aspects of past activity behavior it also contributes to modern clinical research by analyzing cases which would be possible to examine only through radiography and surgery. Non-destructive methods for the skeletal elements are used, since inspection is made with the naked eye. Additionaly, this inspection is fast, effective, and inexpensive.

2. Materials and Methods

2.1 The Middenbeemster cemetery site

Middenbeemster is a province of Noord-Holland and one of the towns of the Beemsterpolder, a World Heritage Site announced by UNESCO in 1999. Inhabitants from the whole Beemsterpolder were interred in the cemetery.

According to UNESCO, the Beemsterpolder dates back to the 17th century and is regarded the oldest area of reclaimed land in the Netherlands. Its original landscape of fields, farms, streets, canals, dikes and settlements has been preserved intact. This unique settlement led to the development of agriculture and farming in this area. Both population size as well as the demand for farmland was steadily increasing since the 16th century (ICOMOS 1999). This led people from the neighboring city of Amsterdam to move and settle to the Beemsterpolder (fig. 6), in the early 17th century; thus Middenbeemster as well as other villages were founded within that region.

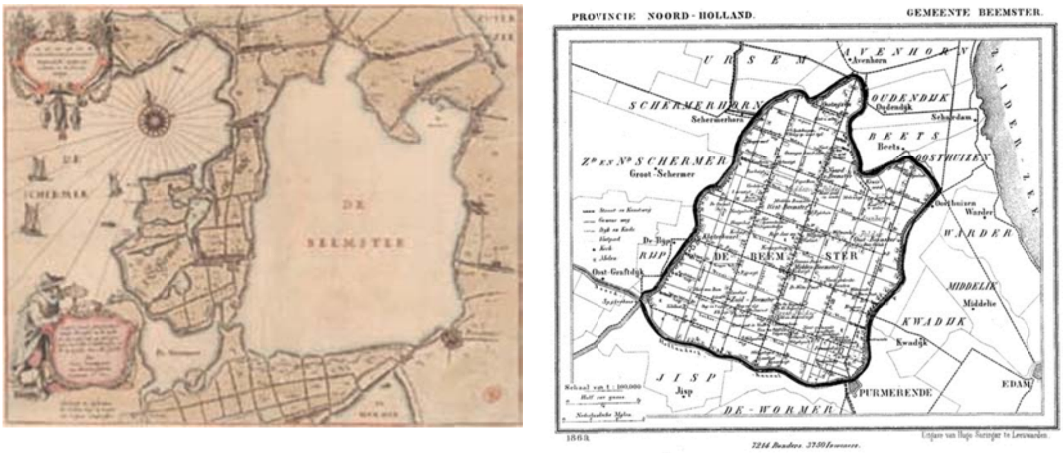

Figure 6: Map of the Beemster
Left: The initial Beemster lake (www.beemsterinfo.nl)
Right: Map of the Beemster polder from 1869, clearly demonstrating the straight lay-out.
(Source:http://www.humanosteoarchaeology.com/uploads/9/7/1/1/9711942/2205567.jpg?628)

The erection of the church started in 1618 and was completed by 1623. It is speculated, according to the archives, that an earlier cemetery might have been located there before the planning of the new church. But this can be proven only by excavation as it probably lies beneath the present church. The graveyard was in use from 1623 until 1866. The last period of use is placed between 1829 and 1866, which is the period for which archival documents are available (Falger *et al.*

2012). The cemetery was emptied and elevated in 1829 resulting in most of the older skeletons being moved to ossuaries, the location of which is unknown (Menno Hoogland personal communication). Consequently, the excavated skeletal sample dates mostly from the later time period. Clay was used for the initial layer of the cemetery, before 1829. Thus, excavated individuals covered in clay are likely to be some of the oldest skeletons that were not removed during the 1829 construction. When the cemetery was cleared in 1829, sand was deposited, instead of clay. Therefore, the deceased from 1829 to 1866 were interred in the final and top layer, consisting of sand.

According to the archives the cemetery should be organized in a checkerboard pattern of graves. Records consisting of birth, marriage, and death certificates were gathered and can provide crucial information regarding the identity of skeletons, especially when it comes to exact determination of sex and age-at-death. A map indicating, with the name of a person on a plot, where everyone from 1829 and onwards is buried can facilitate in the linking of the archives to the skeletons. But unfortunately this procedure has been proven more difficult than expected. Excavations unearthed several levels of graves which were not always consistent with this pattern (van Spelde 2011). Many graves "stacked" on top of each and other resulted in numerous commingled remains of individuals. To complicate things even more, subadults were not interred in a separate area but instead next to and sometimes even through older adult graves (van Spelde 2011). Thus, some clearly discrete and well-defined graves were excavated containing complete or near-complete individuals. But there are also a lot of graves that were not intact and/or exhibit a lot of commingling. Nevertheless, once the linking of the archives to the skeletons is completed, it can provide useful information, particularly for the skeletons that are badly preserved or lack the elements needed to assess sex and age-at-death.

Industrialization of the Netherlands was delayed compared to the neighboring countries. It only started taking place during the second half of the 19th century; and even then the first region to be modernized was the Noord-Brabant and Twente, and not the central region of Amsterdam, within which Middenbeemster is situated (Drukker and Tassenaar 1997). Nevertheless, the Dutch economy, based on its own domestic and agricultural products, was steadily developing (Winde 2006). The reclaimed land of the Beemster polder, an independent municipality since the beginning of the 19^{th} century (De Jong 1998), was no exception to this model. Due to the water table and soil composition the land was gradually converted to meadows for cattle-breeding (De Jong 1998). Therefore, most people were dairy farmers which resulted in a dairy-product based economy, especially cheese. The Beemsterkaas is still famous today. Other trade products contributing to the blossoming of the Beemster economy were wool, butter, and bovine trade (De Jong 1998). Cereal crops were also cultivated, which can serve as food for both humans as well as livestock. The main occupations, other than the archives dating from 1830 until 1835 demonstrate (see Discussion 4.2, Table 11), were animal-herding and farming. This implies that people would engage into different types of activity depending on their main profession. Consequently, the population interred in the Middenbeemster cemetery can be characterized as that of an agricultural community. Thus, the excavated skeletons compose an adequate sample for checking for OD since most of these people would have engaged into strenuous every-day activity, with a high risk of trauma.

2.2 The Middenbeemster sample

Excavations in the post-Medieval cemetery site of Middenbeemster, conducted by Leiden University and Hollandia archaeology in the summer of 2011, unearthed approximately 450 skeletons. The assemblage is housed at the osteological laboratory of the Faculty of Archaeology at Leiden University, in the Netherlands. The collection includes infants, children, adolescents, and adults. Archival records, including sex and age-at-death of 445 individuals from the Middenbeemster area, are available. There is an even sex distribution of 225 females (50.6%) and 220 males (49.4%) and both subadults and adults are included.

One hundred and one skeletons comprised of 46 males, 47 females and 8 adolescents are visually examined for the presence of OD. The degree of preservation of most skeletons is evaluated from good to excellent, with nearly all skeletal elements, present. All synovial joints are checked for the well-defined “crater” lesion. Adolescents around 15 years of age are also examined for osteochondritic lesions since, as mentioned in the introduction, the highest peak of OD occurs in the age category of 10-25 years (Aufderheide and Martín-Rodríguez

1998). All age categories are represented in the sample and the individuals belonging in each category is seen in Table 1.

However, adolescents are excluded from statistical analysis due to the small sample size (n<10) and the fact that sex cannot be determined. In addition, preservation of most of their skeletons is poor and with most of the skeletal elements, important to the current research, either missing or non-observable due to taphonomic processes. Subsequently statistical analysis is based on the remaining 93 adult individuals.

Table 1: Number of individuals of the Middenbeemster sample according to different age categories

Age group (years)	**Number of individuals**
Early young adults (18-25):	14
Late young adults adults (26-35)	25
Middle adults (36-49)	41
Old adults (50+)	13
Adolescents (c. 15-17)	8
∑	**101**

2.3 Methodology

Two of the most important things that need to be determined when analyzing a skeleton are sex and age-at-death. As far as sex estimation is concerned, the methods used are according to “Standards for Data Collection from Human Skeletal Remains” by Buikstra and Ubelaker (1994) as well as the “Workshop of European Anthropologists” (WEA 1980). Sex can only be determined in adults. Regarding age-at-death, a combination of methods is used to achieve as much accuracy as possible. These include dental attrition (Maat 2001), auricular surface morphology (Buckberry and Chamberlain 2002), suture closure (Meindl and Lovejoy 1985), pubic symphysis morphology (Suchey and Brooks 1990) and finally changes to the sternal rib end (İşcan *et al.* 1986).

Skeletons are also checked for degenerative joint diseases such as osteoarthritis (OA), a common pathological condition that can develop due to trauma and movement (Waldron 2008) and can also be a long-term consequence of OD (Aufderheide and Martín-Rodríguez 1998; Schindler 2007; Waldron 2008). In Middenbeemster OA is not usually observed until middle adulthood and according to Waldron (2008) not every joint is equally prone to be affected. For example OA is rarely observed in the ankle and the elbow (Waldron 2008), thus a factor to be considered since it can simplify the diagnosis of suspected OD lesions in these joint surfaces. OA features include porosity, osteophytic lipping and/or eburnation (Waldron 2008). Osteochondritis Dissecans and Osteoarthritis are not connected at an initial stage. Thus, it can be safely assumed that if an OD lesion is detected together with OA, the latter is defined as secondary OA since it is definitely the result of OD. Cases of observed secondary OA on bones affected by OD are noted.

OD lesions are very characteristic. The affected area resembles the shape of a "crater" (Solomon *et al.* 2010, 114) and exposure of the subchondral bone can be observed. If healing has occurred remodeling can be observed (Aufderheide and Martín-Rodríguez 1998). The size of the depression varies depending on the location, but generally the initial defect is approximately 10-20 mm long in circumference and up to 5 mm deep (Aufderheide and Martín-Rodríguez 1998). Pits and depressions occurring on joint surfaces should not be evaluated as OD if they do not fit these criteria since they could simply be normal morphological variants or the result of vascular depressions.

Special methodology regarding the examination of OD on dry bone has not yet been developed. Radiological examination provides a picture of the affected synovial joint with its damaged articular surface, surrounded by a zone of remodeled bone, if present (Aufderheide and Martín-Rodríguez 1998). On dry bone, as already being described, this lesion can be observed with a naked eye. Subsequently, in this thesis the presence of OD is examined macroscopically.

It is common when dealing with archeological assemblages, that not all bones of a skeleton are recovered or when they are, their preservation might be poor to an extent that bone surfaces are not observable. The Middenbeemster collection is no exception to this rule. Subsequently, every retrieved convex and concave joint surface of skeletal elements, that was also observable, is assessed for OD. Naturally, in some individuals, observation of both bones comprising a particular joint is not feasible, either because the elements were not retrieved or they were affected by taphonomic processes.

The steps followed to detect osteochondritic lesions in the given skeletal material are:

1) Visual examination of well-preserved synovial joints. Joints are evaluated as well-preserved depending on their completeness and the extent they were affected by taphonomic processes. Skeletal elements were examined for OD lesions only if more than 75% of the joint surface area was preserved, with minimal visible taphonomic damage. The most commonly affected joints are: i) the knee, ii) elbow, and iii) ankle (Aufderheide and Martín-Rodríguez 1998; Waldron 2008). Other concave and convex joint surfaces, also frequently involved in developing osteochondritic lesions (Bui-Mansfield *et al.* 2000; Gogus *et al.* 2000) are: a) the glenoid cavity of the scapula, b) the distal end of the tibia (tibial plafond), c) the tarsal navicular bone d) the base or the head of the first metatarsal (MT1) and e) the base of the 1st proximal foot phalange. It should be mentioned that apart from these being the most commonly affected areas, they are more likely to be well preserved compared to others such as the wrist or the acetabulum, due to either their robusticity, e.g. the femoral condyles, or the size and thickness of the bone itself, e.g. the talus. In all, six synovial joints were assessed for OD.

2) OD is scored as present or absent. Joint surfaces are scored as “A” (Absence of OD), if they do not have osteochondritic lesions, or “P” (Presence of OD) if they do. Skeletal elements that are missing are recorded with an “M” and when they are available but not observable it is indicated with “n.o”. Some bones have more than one possible surface where OD could occur. For example in the 1st metatarsal (MT1) OD can occur either in the proximal end (base, concave surface) or in the distal end (head, convex surface). In this case if at least one of the two surfaces is present and observable it is assessed for OD. Finally, lesions that resemble OD in both appearance and surface of occurrence, but that are not conclusively OD, are scored as “P?” (Probable OD). These cases will be excluded from statistical analysis in order to present results that are as robust as possible and to keep the dichotomous variable (presence/absence) addressed to the lesion. They will be discussed though at the end of Chapter 3.

3) The size of the lesions are measured and finally

4) All defects, definite or probable, are photographed by the author of the thesis

2.4 Statistical Analysis

OriginPro 8 is used to create charts of the results and SPSS version 19 is used for statistical analysis to evaluate if the observed differences between each category is statistically significant or not. Statistical tests that are used are the independent samples t-test and one-way ANOVA. The former is used for evaluating the occurrence of OD between sexes and sides and the latter for evaluating the occurrence of OD between different age groups and different skeletal elements. When the generated p-value from a statistical analysis is smaller than 0.05 ($p < 0.05$), the differences observed between two or more groups are regarded as statistically significant.

To summarize, based on these steps, it is unlikely that OD lesions will be misidentified and valid results can be obtained regarding the prevalence of this disorder in the examined skeletal material.

3. Results and Statistical Analysis

One hundred and one skeletons were visually examined for the presence of OD. None of the analyzed skeletons had any observable deformations that would have an impact on the individuals' gait. One individual (MB11S270V1067), presented severe deformation of the spine and probably suffered from tuberculosis. His lower limbs and feet were examined and apart from some minor osteophytic lipping on the posterior subtalar facet of both tali no other deformation was noted. Therefore the skeletal elements of his lower limbs and feet are considered as "healthy" and are included in statistical analysis.

All synovial joints were checked for the well-defined "crater" lesion. The knee and the elbow joint showed no OD defects. Lesions were observed only in the glenoid cavities, distal end of the tibia, in one articular facet of a lumbar vertebra and in skeletal elements of the foot. However, as definite OD lesions were assessed only the ones of the foot, which will be discussed shortly.

The following two tables (Tables 2 and Table 3) show all females and males with OD lesions with sex and age-at-death information and the location of the OD lesion. Both tables exhibit the ankle and foot bones. This is firstly because OD was definitely assessed in the tarsals and metatarsals. Secondly, the distal end of the tibia and the dome of the talus comprise the ankle joint and despite the fact that lesions occurring in the distal end of the tibia are assessed as probable OD, the latter is included in the table to demonstrate a better picture of the individuals' foot condition. Finally, Table 4 shows abbreviations used for the examined skeletons.

Table 2: Females with OD in the Middenbeemster sample

Skeleton ID	Sex	Age (years)	Tibia		Talus		Navicular		MT1		1st p.p.	
			L	R	L	R	L	R	L	R	L	R
MB11S045V0055	F	36-49	A	A	A	A	A	A	A	A	P	A
MB11S053V0290	F	36-49	A	A	A	A	A	A	A	A	P	M
MB11S356V0864	PF	36-49	A	A	A	A	A	A	A	A	P	P
MB11S370V0806	F	26-35	A	A	A	A	A	A	A	A	A	P
MB11S420V0936	F	26-35	A	A	P	A	A	A	A	A	A	A

Table 3: Males with OD in the Middenbeemster sample

Skeleton ID	Sex	Age (years)	Tibia		Talus		Navicular		MT1		1st p.p.	
			L	R	L	R	L	R	L	R	L	R
MB11S158V0427	M	36-49	A	A	A	A	A	A	A	P	A	A
MB11S162V0316	PM	40-50	A	A	A	P	A	A	A	A	M	A
MB11S233S0304	M	>40	P?	A	A	A	A	A	A	A	P	A
MB11S290V0472	M	18-25	A	A	A	A	A	A	A	A	P	P
MB11S317V0649	M	50+	A	P?	A	A	P	P	A	P	A	A
MB11S337V0714	M	50+	A	A	P	A	A	A	A	A	A	A
MB11S347V0741	M	50+	A	P?	A	A	A	A	A	A	A	P
MB11S379V0851	M	18-25	A	A	A	A	A	A	P	P	A	A
MB11S411V0904	M	36-49	A	A	A	A	A	M	P	P	M	A

Table 4: List of used abbreviations

A	Absence of OD, skeletal element present	
P	Presence of OD, skeletal element present	
P?	Probable OD lesion	
M	Missing skeletal element	
n.o.	non-observable surface of skeletal element	
L	Left	
R	Right	
M	Male	
PM	Probable Male	
F	Female	
PF	Probable Female	
MT1	First metatarsal	Head of MT1 and base of 1st p.p. → First metatarsophalangeal joint (1st MTJ)
1st p.p.	First proximal foot phalange	

As observed in Table 2, five females were affected. The 1st proximal foot phalange was involved in four cases, one of them bilateral, and the talus was affected in one individual with the lesion occurring on the posterior subtalar facet. In the case of the talus, the lesion was 6.0 mm long and its margins were smoothed with slight eburnation present, thus indicating secondary OA.

When the 1st proximal foot phalange is involved, the lesion appears in the center of the base. The length varies from 1.0 mm to 4.0 mm. The largest lesion was observed in individual MB11S045V0055, where marginal lipping was also noted. The lesion in individual MB11S053V0290 had signs of healing since remodeling of the area was observed, but no signs of OA were recorded. Individual MB11S370V0806 had the smallest lesion and no signs of OA. In individual MB11S356V0864, the bilateral case, the lesion was small in both phalanges (1mm) but marginal lipping and eburnation was present on both of them being more pronounced on the left (secondary OA). However, the corresponding head of the MT1 had no signs of degeneration.

It is evident from Table 3 that more males than females are affected by OD (n=9). The lesion occurred in six cases in the MT1, two of which were bilateral. The 1st proximal foot phalange was involved in four cases, with one bilateral occurrence. Two individuals bared OD lesions on the talus and finally in one individual both naviculars were affected. Lesions that are possible OD were observed in the distal end of the tibia in the medial side in three individuals, but as it will be discussed at the end of the chapter their diagnosis is debatable and thus they are excluded from statistical analysis.

Lesions in the MT1 appear either on the head or base. When occurring in the head, they are located in the center and measure between 2.0-4.0 mm in length. Lesions on the base of the MT1 appear also in the center measuring 0.5-4.0 mm in length. Finally when the proximal phalange is involved, lesions are located in the center of the base and measure 0.5-3.0 mm. As observed from Table 3, there are no cases where both the MT1 and the proximal foot phalange, comprising the 1st metatarsophalangeal joint (1st MTJ), are involved. Finally, in eight of the nine individuals there are no signs of OA. In individual MB11S347V0741there is mild marginal lipping and porosity on the base of the proximal phalange, therefore indicating secondary OA of the 1st MTJ. However, no signs of eburnation were detected.

Lesions involving the posterior subtalar facet are observed in two individuals (MB11S162V0316 and MB11S337V0714). The depression in the first case (fig. 4) is approximately 10 mm long and marginal lipping is observed on the posterior subtalar facet. In the second individual the lesion is 5.0 mm long and appears to be in an initial phase since the margins are not well defined and there appears to be no bone remodeling. Slight marginal lipping is observed on the posterior-lateral side of the posterior facet as well as on the lateral side of the anterior subtalar facet. The navicular was involved in one bilateral case (MB11S317V0649) (fig. 2). OD appears symmetrically on the proximal articular facet. The left lesion is 9.0 mm long whereas the right measures only 2.0 mm and could therefore be at an initial stage since there is no further evidence of bone degeneration due to the lesion.

Finally, it should be mentioned that one of the adolescents (MB11S446V0944), approximately 16.5 years old, was affected by OD on the posterior subtalar facet of the left talus. This occurrence is consistent with clinical literature that places the onset age of OD in early puberty and therefore indicates that the adolescents in the Middenbeemster collection could be an interesting age group to analyze once they are all available.

3.1 Prevalence of OD in the Middenbeemster sample

In the Middenbeemster sample the crude prevalence of OD (number of individuals affected) among the adults is 14 out of 93 (14/93), which yields a percentage of 15.1. Surprisingly, none of the skeletons with both knees observable (67/93) had OD lesions in that joint. Additionally, six more skeletons had only a portion of either one of the two femoral condyles, from only one of the two knees, missing or non-observable. Thus, with three out of four femoral condyles available for observation, the sample size slightly increases to 73/93. Likewise, no case of OD of the elbow was observed; regarded as the second most common site of OD after the knee. Consequently, the earlier stated frequency of 15.1% corresponds to osteochondritic lesions located in the foot, the third most common region to be affected according to clinical literature.

3.1.1 Distribution of OD between sexes

The tendency of males to be affected by OD more often than females (Aufderheide and Martín-Rodríguez 1998) is observed in the Middenbeemster sample. Nine out of 46 (19.6%) male individuals suffered from OD in one or more skeletal elements of the foot whereas five out of 47 (10.6%) females are affected. Figure 7 shows the prevalence of OD between sexes.

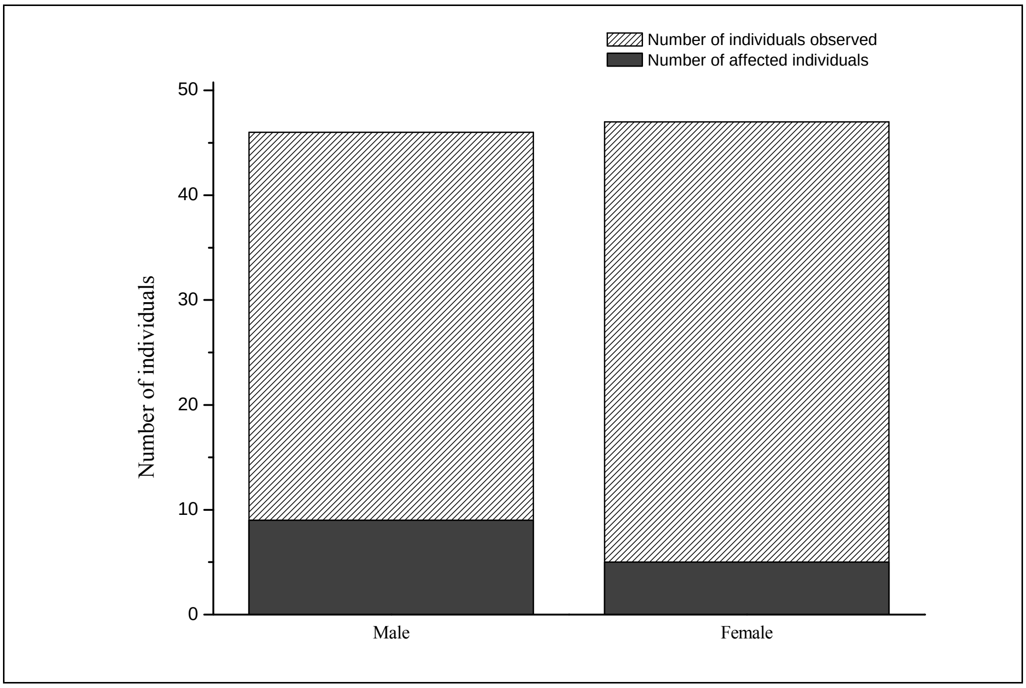

Figure 7: Distribution of OD between sexes

The 1st proximal foot phalange is the most commonly affected bone for both sexes with five cases occurring in females and four in males. This is followed by the talus with two cases occurring in males and one in females and lastly the MT1 and the naviculars were affected only in males (Table 5). Figure 8 exhibits the distribution of OD in the different skeletal elements of the foot, between sexes.

Table 5: Distribution of OD in the different bones of the foot between sexes

Skeletal elements of the foot	**Male**	**(%)**	**Female**	**(%)**
1st proximal foot phalange	4/60	6.7	5/64	7.8
Talus	2/81	2.5	1/75	1.3
MT1	6/76	7.9	0/75	0
Navicular	2/70	2.9	0/64	0
∑	**14/287**	**4.9**	**6/278**	**2.2**

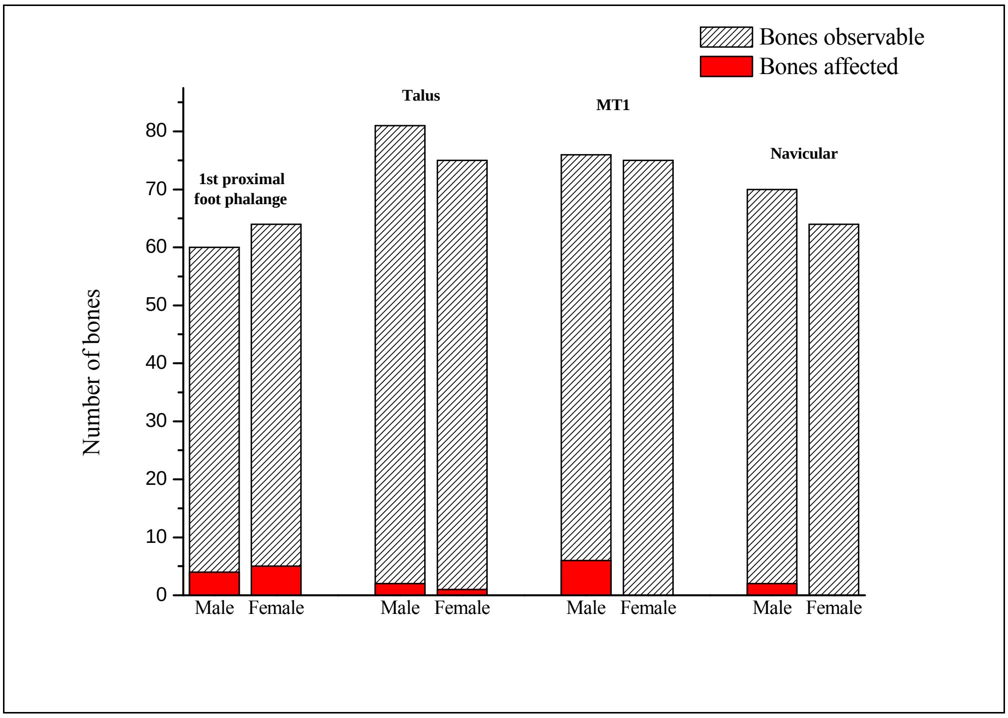

Figure 8: Distribution of OD in the different bones of foot between sexes

3.1.2 Distribution of OD between left and right side

In both left and right foot, 10 bones from each side were affected as seen in Figure 9:

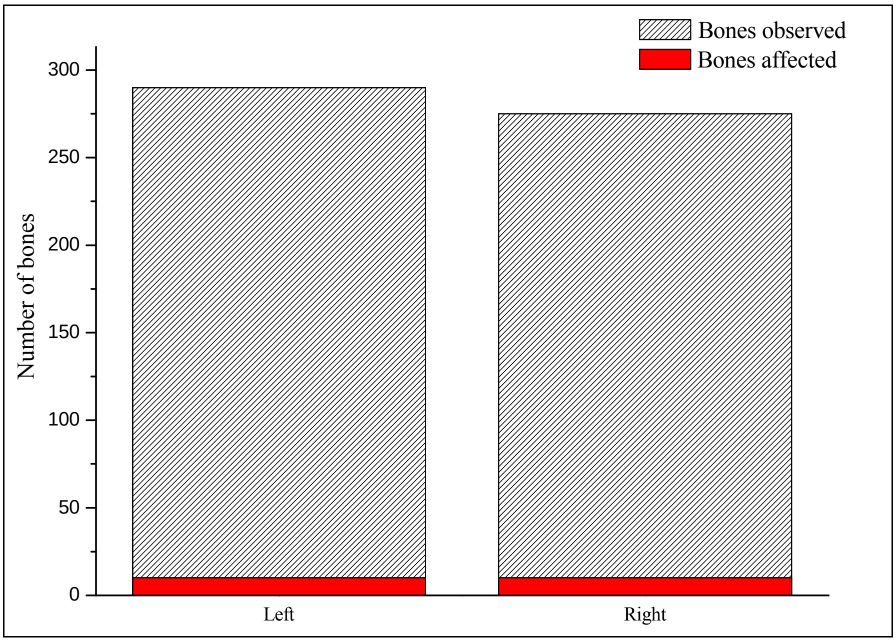

Figure 9: Number of affected skeletal elements between left and right foot

The distribution of OD between the different skeletal elements of the left and right foot is described in Table 6 and Figure 10:

Table 6: Distribution of OD between bones of the foot between left and right side, regardless of sex

Skeletal elements of the foot	**Left**	**(%)**	**Right**	**(%)**
1st proximal foot phalange	5/63	7.9	4/61	6.6
MT1	2/76	2.6	4/75	5.3
Talus	2/81	2.5	1/75	1.3
Navicular	1/70	1.4	1/64	1.6
∑	**10/290**	**3.4**	**10/275**	**3.6**

In both cases the 1st proximal foot phalange is the most frequently affected with five cases occurring in the left foot and four in the right. The MT1 is the second most commonly skeletal element involved in osteochondritic lesions with two and four cases occurring in the left and right side respectively. Finally, the talus and the navicular present the lowest frequency of OD occurrence.

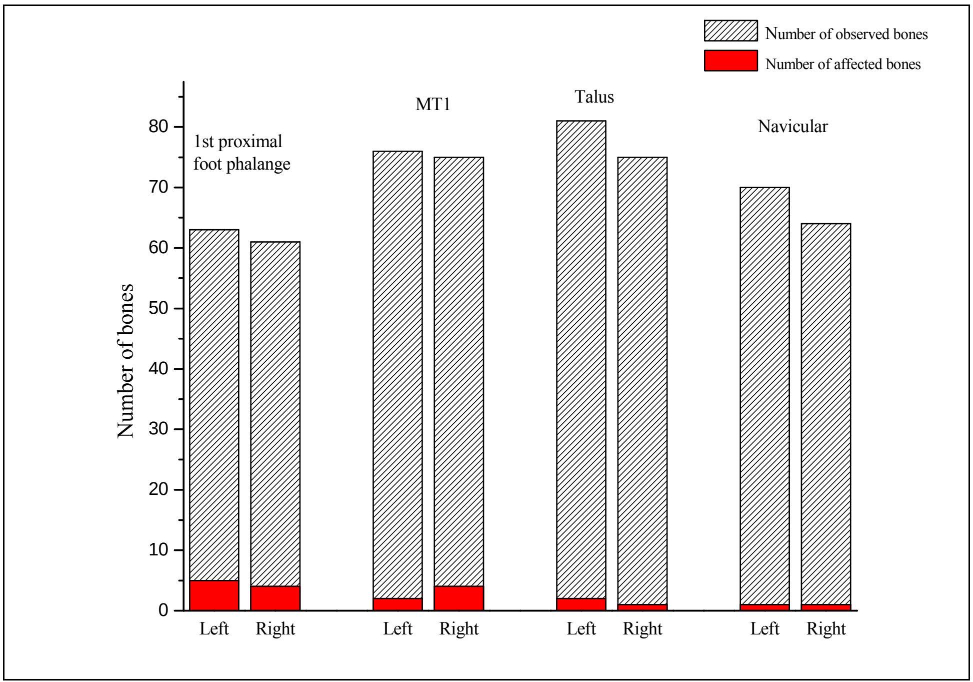

Figure 10: Distribution of OD between the skeletal elements of left and right foot, regardless of sex

3.1.3 Distribution of OD in different age groups

The sample is divided into four different age groups. The group represented by the most individuals, 41, is that of middle adults ranging from 36 to 49 years. The highest frequency of OD, 23.1%, is observed in old adults followed by the middle adults with 17.1%. The lowest frequencies are observed in early young adults and late young adults with 14.3% and 8.0% respectively. However, as seen in Table 7, sample sizes in each age group are not equal. Therefore these percentages are only indicative for the available skeletons and cannot be regarded as true prevalence of OD between different age groups for the entire population.

Table 7: Distribution of OD between different age groups

Age group (years)	**Number of cases per observed skeletons**	**Percentage (%) per age category**
Early young adults (18-25):	2/14	14.3
Late young adults (26-35)	2/25	8.0
Middle adults (36-49)	7/41	17.1
Old adults (50+)	3/13	23.1
∑	**14/93**	**15.1**

Figure 11 shows the distribution of OD between different age categories. The fact that the highest frequency is observed in older individuals should not be confused with the onset age of OD in early adulthood, according to clinical literature (Schenk *et al.* 1996). In the current sample, there is no way of knowing when the affected individuals first developed OD. Therefore, it can be assumed that individuals affected at a young age and lived long enough, resulted in an accumulation of the observed lesions in the older age categories and particularly in the old adults (50+ years).

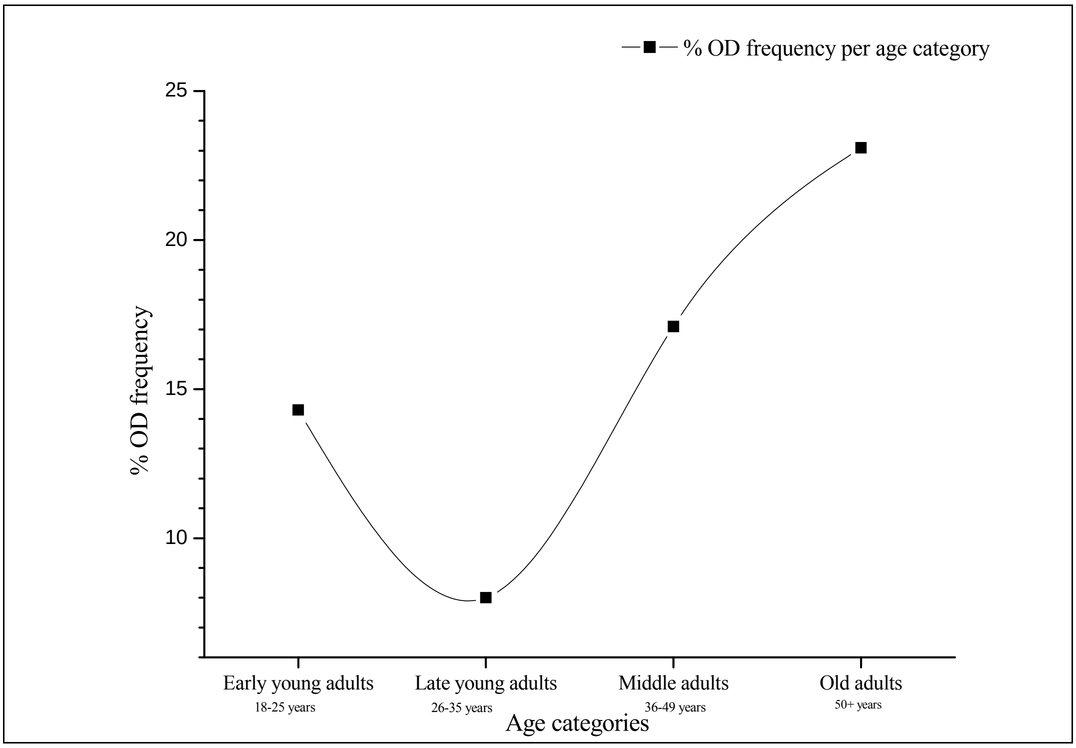

Figure 11: Distribution of OD in different age categories

3.1.4 Distribution of OD in different joint surfaces of the foot

The talus, the navicular, the MT1, and the first proximal foot phalange were the bones affected the most by OD. Five hundred and sixty five bones belonging to one of the above categories were observed and 20 of them had OD defects, resulting in a frequency of 3.5%. Subsequently, since the defect is localized in these bones, the latter percentage will be regarded as OD prevalence of the foot in the current sample. The distribution of OD lesions between these bones is as displayed in Table 8.

Table 8: Distribution of OD in the different skeletal elements of the foot

Bone	**No. of bones**	**Frequency (%)**
1st proximal foot phalange	9/124	7.3
1st metatarsal (MT1)	6/151	4.0
Talus	3/156	1.9
Navicular	2/134	1.5
∑	**20/565**	**3.5**

In the Middenbeemster sample the 1st proximal phalange is the most commonly affected bone, followed by the MT1 and the talus. Finally, in one case, both naviculars from the same individual had OD lesions on the proximal articular surface.

<u>3.1.5 Bilateral cases and multiple joints involvement</u>

Several individuals were affected bilaterally by OD. More specifically: i) one female had OD lesions in the base of both 1st proximal foot phalanges and ii) four males were affected bilaterally in three different joint surfaces. One case was observed in the 1st proximal foot phalange. The second case was the bilateral involvement of the navicular. The same individual was also affected on the proximal end of the right MT1, therefore the involvement of multiple different joints is also observed in this individual (MB11S317V0649). Finally, the third and fourth bilateral occurrence, involved the MT1 with the head being affected in one case and the base in the other.

<u>3.2 Results from statistical analysis</u>

<u>3.2.1 Difference between sexes</u>

An independent samples t-test analysis was used to examine whether there was statistically significant difference between the frequencies of observed OD lesions in the two sexes. While there is a difference in the number of males and females with OD, the difference is not statistically significant as indicated by the generated values ($t=1.200$; $p=0.233$)

<u>3.2.2 Difference between sides</u>

An independent samples t-test analysis was also used to examine whether the occurrence of OD between the left and ride side was statistically significant. The generated values ($t=0.121$; $p=0.904$) clearly indicate that there is no statistically significant difference between sides

<u>3.2.3 Difference between the age groups</u>

To test the difference in OD frequency between age categories a one-way ANOVA test was used. The p-value ($F=1.437$, $p=0.237$) shows that there is no overall statistically significant difference between different age groups. Multiple comparisons were also conducted, using the post-hoc Tukey HSD test, to check whether there was any statistically significant difference between two certain categories. As observed in Table 9 from the generated p-values, there clearly is not since they are all larger than 0.05.

Table 9: p-values generated from the post-hoc Tukey HSD test

	Early young adults	**Late young adults**	**Middle adults**	**Old adults**
Early young adults	-	0.726	0.282	0279
Late young adults	0.726	-	0.844	0.743
Middle adults	0.282	0.844	-	0.973
Old adults	0.279	0.743	0.973	-

3.2.4 Difference between different skeletal elements of the foot#

The one-way ANOVA test was also used to check for statistically significant differences between the different skeletal elements of the foot. The p-value is higher than 0.05 (F=1.709, p=0.164) and therefore no statistically significant difference is observed. Multiple comparisons were also computed to check for any statistical significant difference between any of the skeletal elements. As shown in Table 10 there is none.

Table 10: Multiple comparisons showing p-values generated from post-hoc Tukey HSD test.

	Talus	Navicular	MT1	1st prox.phal.
Talus	-	0.931	0.700	0.461
Navicular	0.931	-	0.356	0,196
MT1	0.700	0.356	-	0.973
1st prox.phal.	0.461	0.196	0.973	-

To summarize, there appears to be no statistically significant difference in the occurrence of OD between the sexes, left and right side, or within the different age groups. Finally, between the four different skeletal elements of the foot examined, no statistically significant difference was observed.

3.3 Probable cases of OD

Some skeletons in the Middenbeemster sample displayed lesions that resemble the ones caused on the joint surface by OD. However, the early stages of

OD, before the detachment of the bone-cartilage fragment but following destruction of cartilage, lack classification criteria. Consequently, skeletal elements bearing lesions similar to OD but lacking the well-defined "crater" shape lesion, where the trabecular is exposed, were evaluated as "probable" OD cases and were excluded from statistical analysis. The joint surfaces exhibiting "probable" OD lesions in the current sample are stated below:

1) The center of the glenoid cavity of the scapula

The shoulder joint is often involved in strenuous activity therefore the chances of the development of generative diseases, such as OA, are increased. There are four individuals with scapulae that have probable OD of the glenoid cavity. The lesions of the glenoid cavity of the sample had either a small depression, but no porosity of the exposed trabecular was observed, or in the cases where pitting and porosity were present, the lesions lacked the characteristic depression of OD and were on the same level with the joint surface. In the former case, apart from OD, the depression could be either the result of taphonomy or simply normal morphological variation. In the latter case (fig. 12, fig.13) the observed porosity and pitting could be the initial phase of joint surface degeneration since neither lipping or eburnation were present, which are indicative of developed and final stages of OA, respectively (Waldron, 2009).

Figure 12: Probable OD lesion of the glenoid cavity of a female skeleton. Note that in this individual the lesion could also be so well healed that the depression is almost absent making diagnosis difficult.

Figure 13: Bilateral probable OD lesions on the glenoid cavities of a male skeleton. This particular individual had OD on the posterior subtalar facet

2) The medial surface of the distal end of the tibia on the posterior side of the malleolus process (fig. 14)

The occurrence of OD in the distal end of the tibia is poorly understood and even less described. Radiology literature is practically non-existent with the entity being described in only one textbook and without precise references (Bui-Mansfield 2000). Additionally, the ankle is a highly vascular region with numerous arteries and veins further divided into branches creating a complex net (Drake *et al.* 2010). These factors, combined with the imposed forces on the ankle joint, might result in vascular depressions mimicking OD lesions. Finally, depressions in the distal end of the tibia could also be the result of defects during ossification processes (George Maat, personal communication).

Figure 14: Depressions located in the distal end of the tibia on the medial side on the posterior side of the malleolus process

3) The right inferior articulate facet of the 5th lumbar vertebra (L5) (fig. 15)

One lesion demonstrating all characteristics of OD was detected in the right inferior articular facet of the L5 in a male individual (MB11S368V0794). Posterior intervertebral joints are regarded as synovial joints of limited movement. Therefore, considering that the L5 suffers high pressure this defect could be a case of trauma induced OD. No case however of OD occurring in the spine has been reported in clinical literature.

Figure15:Probable osteochondritic lesion on the right inferior articular facet of the L5 of a male individual

4. Discussion

According to clinical literature, OD in humans occurs approximately in 15 to 30 people per 100.000 of general population, annually; thus considered a rare disease (Gogus *et al.* 2008) with an approximate prevalence of 0.02%. The analysis of the Middenbeemster skeletal assemblage has yielded interesting results. It is evident that the frequency of OD in this sample (15.1%) is different and a lot higher than general population prevalence. Furthermore, all three analyzed Dutch populations compared to the non-Dutch, analyzed by Ponce in Chile (2010) and Bourbou in Crete (2010), indicate that the prevalence of OD in the Netherlands is generally high.

Industrialization, as will soon be discussed, came in the Netherlands near the end of the 19th century and therefore, the level of activity between different social ranks, is not expected to demonstrate large fluctuations between different time periods, prior to industrialization. Thus, the fact that the three furtherly discussed Dutch collections, are from different time periods, is of little significance since it is the level of activity that is investigated and the latter is influenced more by social rank and/or whether the individuals belonged in a rural or urban society.

Dutch skeletal samples from Alkmaar and Dordrecht, both dating from medieval years, demonstrate OD frequencies, of 4.8% and 3.5% respectively. Both of them are higher than the general prevalence (0.02%) but a lot lower than that of Middenbeemster, 15.1%. This could be attributed to the fact that the skeletons from Alkmaar and Dordrecht belong to individuals of higher social status, from an urban society and they would subsequently, engage into less strenuous activity compared to the ones from Middenbeemster, which belong in a rural society of lower social status. This high percentage of 15.1% of the Middenbeemster population indicates that strenuous activity and trauma, two of the most probable causes for OD, must have been common. The following graph (fig. 16) shows the prevalence of OD in the Dutch populations.

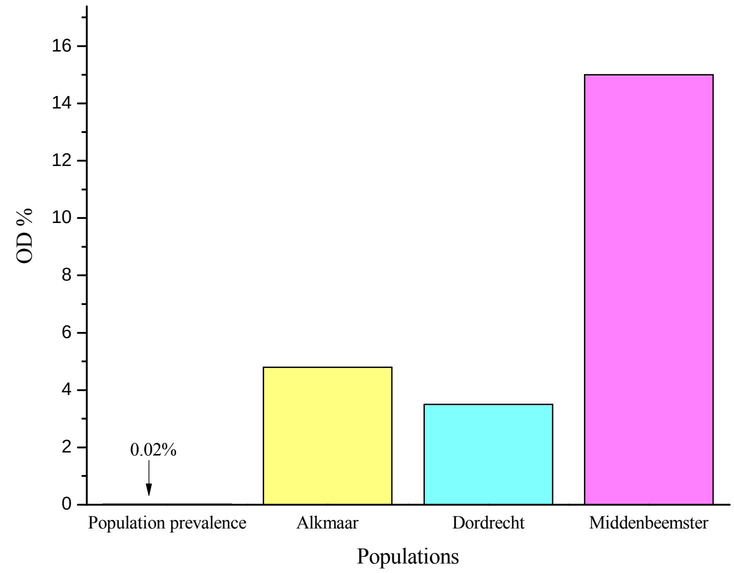

Figure 16: Distribution (%) of OD in Dutch populations and compared to the general population prevalence

4.1 OD in Dutch populations

The first research question was to investigate whether the frequency of OD in an almost exclusively agricultural society would be relatively high, since people would engage in more strenuous activity, compared to populations from urban societies. The high frequency of OD (15.1%) observed in the Middenbeemster sample, indicates that OD is likely to be associated with vigorous activity. Life in Dutch rural communities of the 19th century, such as the Middenbeemster, was quite tough. People engaged in physically demanding outdoor occupations often working in harsh weather conditions (Lindeboom *et al*. 2012). Rural women would often work in the fields, helping their husbands and leaving their children at home to be looked after their grandmothers (Lindeboom *et al*. 2012). Furthermore, children, younger than three years old, were expected to assist their mothers and/or grandmothers with the household (Gerard *et al.* 2002) before they were old enough, over four years of age, to work in the fields with their parents (www.openluchtmuseum.nl). This stated, the theory of trauma can also be supported since farmers and cattle-breeders, being the main occupations of the Middenbeemster population according to the archives, are expected to be regularly involved in “accidents” occurring either while working in the field cultivating land, or from their interaction with animals.

Figure 17: Wood gatherers in the snow, painted by Van Gogh in September 1885 (www.vggallery.com)

Figure 18: Women Mending Nets in the Dunes (Van Gogh 1882) (www.vggallery.com)

Figure 19 Farmers Planting Potatoes (Van Gogh 1884) (www.vggallery.com)

Van Gogh's paintings (fig. 17, fig. 18, fig. 19) illustrate the rough life conditions of rural societies during the end of the 19th century. The first painting shows a Dutch family gathering wood in the snow, whereas the second and third paintings demonstrate women working in the fields.

As already mentioned, according to clinical literature the knee joint is most frequently affected by OD. In the Middenbeemster sample however, no knees were affected, something expected to occur due to strenuous activity possibly combined with trauma. Nevertheless, it should be reminded that "absence of evidence is not evidence of absence" since there were at least 20 individuals who had either both knees missing or whose knee surfaces were too eroded from taphonomy to be evaluated. But this is yet one of the shortcomings of archaeology; having often to work with incomplete data. It should be mentioned that there was also no report of OD of the knee in the Alkmaar collection (Schats 2012). However, if the general prevalence of OD (0.02%) is kept in mind, the zero incidence of OD in the knee of 93 skeletons is not erroneously inconsistent since the sample size is relatively small. The same applies to the capitellum of the humerus, for which no OD was assessed, for the 93 individuals.

To summarize, strenuous activity possibly combined with trauma, resulted in the high observed frequency of OD of the foot in the Middenbeemster sample.

4.2 OD correlated to sex and age

The second research question referred to whether there is a significant variation in OD frequency between the sexes and different age groups that could be correlated to different amounts of activity between these groups. The results of the statistical analysis show no significant difference in OD occurrence between males and females and between different age-categories. Therefore, the incidence of trauma can be once again regarded as the primary factor causing OD since every person in a rural society, would be more susceptible, regardless of sex and age group.

Looking at different ages more specifically, the chance that younger individuals are more prone to developing OD is, as already discussed in the introduction, consistent with clinical research that proposes an onset age during young adulthood (Schenk *et al.* 1996). Therefore, the older an individual was, the less likely they would be to develop OD. In the current sample, however, as displayed in the results (paragraph 3.2.3), the highest frequency occurs in old adults. As explained earlier, this accumulation of OD lesions can simply be due to the fact that these individuals were affected at a young age and lived through young adulthood, bearing the lesion. This may also fit, into the theory of trauma being the primary cause of OD in the sample, since younger individuals would be expected to work more in the field than older ones. Schenk *et al.* (1996) note, in a modern study, that the symptoms of OD of the ankle are vaguely described and can be consistent with the ones of a sprain, since most of the patients suffering from OD of the ankle reported previous injury to the joint describing it as sprain. The level of pain can vary and when it is first noted it usually depends on the stage of the lesion (Schenk *et al.* 1996). Therefore, considering the hard conditions of life during the 19th century in rural communities, it can be assumed, that people were not often given the opportunity to rest, a factor that could contribute in the healing of lesions. If they were involved in a small accident, e.g. an ankle sprain, they would probably not follow any treatment such as simple immobilization. Instead they would continue working with an injury.

As far as sex in concerned, in spite of the almost 1:2 ratio of affected individuals between females and males, the statistical analysis finds no significant difference between the sexes. This may be partly due to the small sample size of the collection. Another alternative, though, might be that females were exposed to similar and/or the same stressful conditions as males, since according to Lindeboom *et al*. (2012) and as illustrated in Van Gogh's paintings (fig. 18, fig. 19) rural women spent their day working in the field. Subsequently, they engaged in the same strenuous activities as men which would explain the non-significant difference of observed OD between sexes. Thus, the theory of trauma being responsible could apply also to females who could have quite easily been involved in an accident occurring either outdoors or indoors while performing household chores. Their level of activity cannot be safely estimated, but in any case, an untreated trauma on the foot, could lead to developing OD. At this point consulting the archives would be a tremendous source of information since professions of the deceased have been registered. The archives from 1830 to 1835 reveal numerous professions as seen in Table 11, besides farming and animal herding.

Table 11: List of professions from 1830-1835 from the region of Beemster

Workers	Cargo drivers	Servant girls
Tailors	Garden aids	Mill bosses
Handmaidens	Saddle makers	Innkeepers
Housewives	Village policemen	Gardeners
Sailors	Cobblers	Bakers
Water millers	Merchants	Carpenters
Preachers	Tailor's servants	"Bode"
Artists	Housekeepers	"Kastelein"

There are two professions, "Bode" and "Kastelein" that cannot be translated into English. A "*bode*" is a person working in the town council delivering letters and a "*kastelein*" can be either a bailiff, a steward, or a tavern keeper. The analysis of linking the archives to specific individuals from the Middenbeemster is still in progress. Nevertheless, it is quite evident from the professions listed above that accidents resulting in trauma of the foot can easily occur in most of them, practiced either by males or females.

4.3 OD correlated to left and right side

Finally the third goal of this research was to investigate if either the right or left side is more prone to developing OD. The answer to this question is no, since the difference in occurrence of OD observed between the left and right foot was not of statistical significance. This comes as no surprise considering that pressure is equally distributed on both feet, from every-day activities such as walking. In an agricultural society of the mid-19th century, extensive walking due to farming and herding activities would result in an increase of both stress and chance of accident occurring, with equal probability in either foot. Walking on a rough and uneven ground surface, as the one often encountered in the country side, would result in increased amount of stress on the feet.

Trauma, due to accident, also fits this picture since the probability of it happening in such an environment would be augmented. This could also explain why certain individuals were affected either bilaterally or in more than one different bones of the foot.

4.4 OD of the ankle joint and clinical research

There is general consensus that the etiology of OD is multifactoral. In modern societies, OD of the ankle is rare since the ankle joint is involved in only 4% of the general prevalence (Bui-Mansfield *et al.* 2000). However, underestimation of the disease can be expected due firstly, to the fact that initial stages can be asymptomatic or resemble the symptoms of a sprain (Schenk *et al.* 1996). Consequently affected people are unaware of developing OD of the ankle until it reaches a final stage with pain and discomfort as main symptoms. Secondly, the overall etiology of the disease still remains to be clarified.

Bruns and Rosenbach (1990) investigated the contribution of biomechanical factors, such as trauma and overloading stimuli, to the development of OD of the talus bone of the ankle. They used a cadaveric biostatic model to evaluate the difference in pressure distribution on the ankle joint in various joint positions, therefore mimicking ligamentous supination and pronation trauma. They saw that the maximum amount of pressure, in several positions, was observed in the same region of the talus where OD lesions occur. This indicates that shifts in the distribution of load on the talar surface may result in osteochondritic lesions suggesting trauma as important etiology.

Additionally, Athanasiou *et al.* (1995) calculated the thickness and mechanical properties of the cartilage surrounding the ankle joint and found that the talar cartilage was softer than the tibial, which was stiffer. This would explain why OD of the talus is more common than the OD of the distal end of the tibia. Thus, the factors that contribute to OD of the distal end of the tibia remain unclear. The results of the research, however, can be restricted since the number of cadavers was limited to only seven therefore leaving space for anatomic variation. In fact, Bui-Mansfield *et al.* (2000) suggest that some people might have softer cartilage surrounding in the distal end of the tibia which would subject them to a higher risk for developing OD. Additionally, they exclude ischemia since the ankle joint is a highly vascular region. Therefore, injury is proposed as the most probable cause for OD of the distal end of the tibia (Bui-Mansfield *et al.* 2000).

Both previous studies deal with the biomechanical properties of the surrounding ankle cartilage. This explains why the area of the ankle is more delicate than the other joints, especially when compared to the surface of the knee joint. The knee surface is larger than the one of the ankle. Consequently, in the ankle more weight is distributed on a smaller surface therefore making the ankle joint as the one that undergoes the most stress in the entire body. Therefore injury of cartilage is proposed as the most probable cause for OD in this area.

However, injury implies that some kind of impact was imposed on the foot and the studies do not examine how the rest skeletal elements of the foot are affected in that case. Additionally, clinical literature referring to other bones of the foot been affected by OD is extremely rare and therefore their exact prevalence unknown. Only a small number of case reports are published such as OD of the navicular (Bui-Mansfield *et al.* 2000), OD of the MT1 (Bojanić *et al.* 2011), and OD of the medial cuneiform (Anderson 2002).

Consequently, according to previous studies, the talus would be expected to have the highest frequency of OD in the Middenbeemster sample. But instead the 1st metatarsophalangeal joint was involved in most cases (8/14), with either the head of the MT1 or the base of the 1st proximal phalange being affected. Furthermore, even when the talus was involved, OD was observed on the posterior subtalar facet and not on the dome where it should be expected to occur. So could there be another factor contributing to this strange distribution of OD lesions in the skeletal elements of the feet?

4.5 "*De Klompen*"

Referring to the remark made by Wells (1974), who used OD as a marker for the transition to agriculture in the British Isles, he suggested that the occurrence of OD was attributed to trauma, due to poor footwear and insufficient equipment used in an effort to make land exploitable.

If the Middenbeemster society is examined more carefully certain similarities can be observed. First of all, as already explained, it was primarily an agricultural society therefore the chances of trauma were increased compared to a more urban society. Secondly, the type of footwear mostly worn in the

Netherlands during that time was the *klompen*. These wooden shoes, generally known as clogs, could be responsible in the high occurrence of OD observed in the foot and particularly in the 1st metatarsophalangeal joint. When worn, the hard and inflexible surface of the shoe, would limit the natural range of movement of the foot. Furthermore, if someone tripped while wearing clogs, the impact induced on the toe could be equivalent to knocking the foot against a hard surface.

Clogs come in various forms and shapes. Sometimes they are stuffed with straw or made up of an upper layer of leather (De Boer-Olij 2002). But in every case the sole is made of wood (De Boer-Olij 2002), thus being a rather hard and inflexible surface to walk on.

Each time our foot is lifted to take a step there is a chance of stumbling since balance is maintained on only one foot, even if it is for an unnoticeable amount of time. The action of stumbling would have an even higher probability of occurrence in an uneven terrain such as encountered in agricultural fields. If a stumble occurred while a person was wearing clogs, skeletal elements of the foot and the toe in particular, would suffer a severe impact. Repetition of stumbling could eventually result in injury of the 1st metatarsophalangeal joint, since it is usually the first region to be affected and could also result in injuries of the tarsals depending on the severity of impact.

Subsequently, it is proposed that the high level of activity combined with frequent incidence of trauma is responsible for the high percentage of observed OD lesions in the Middenbeemster population sample. Additionally, the common use of the *klompen* may be responsible for the distribution of OD lesions observed among skeletal elements of the foot.

4.5.1 "Tale as old as time"

Klompen in the Netherlands have been worn extensively at least as early as the beginning of the 13th century, as the oldest wooden shoe ever retrieved and kept in Amsterdam, dates back to 1213 AD. De Boer-Olij (2002), in her book "European wooden shoes", provides numerous examples of wooden shoes that accompanied every event of daily life, in the region of the Netherlands as well as other regions of northern Europe. Wooden shoes were not worn only by common people but also by nobility with their status being indicated from the beautiful carvings and decorations on the front of the shoe (De Boer-Olij 2002).

Decorations were also indicative of the geographic origin of the shoe (De Boer-Olij 2002). Painting and decorating the *klompen* was even a recognized profession (De Boer-Olij 2002). Decorated wooden shoes (fig. 20) were usually worn on Sundays or during festivities. They were even used as a means of marriage proposal (De Boer-Olij 2002).

Apart however, from the nicely decorated *klompen*, special wooden shoes were used during winter to protect the foot from the cold. Dikers wore special square nose wooden shoes that facilitated working on the knees when they put basalt blocks on the sea dikes (fig. 21) (De Boer-Olij 2002). Another type was the horse sledge shoe only used by nobility. It was screwed onto the sledge and the shoes were pushed in (De Boer-Olij 2002).


Figure 20:Decorated shoe with owners' initials drawn on the upper side (De Boer-Olij 2002, 37)

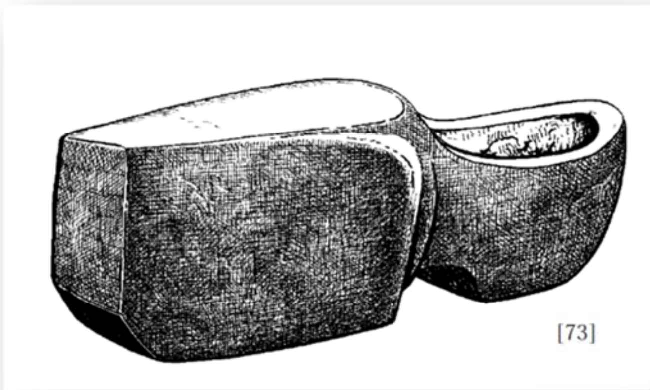

Figure 21: Square nose wooden shoe (De Boer-Olij 2002, 44)

Figure 22: Peasant Woman Sweeping the Floor (Van Gogh 1885) (www.vggallery.com)

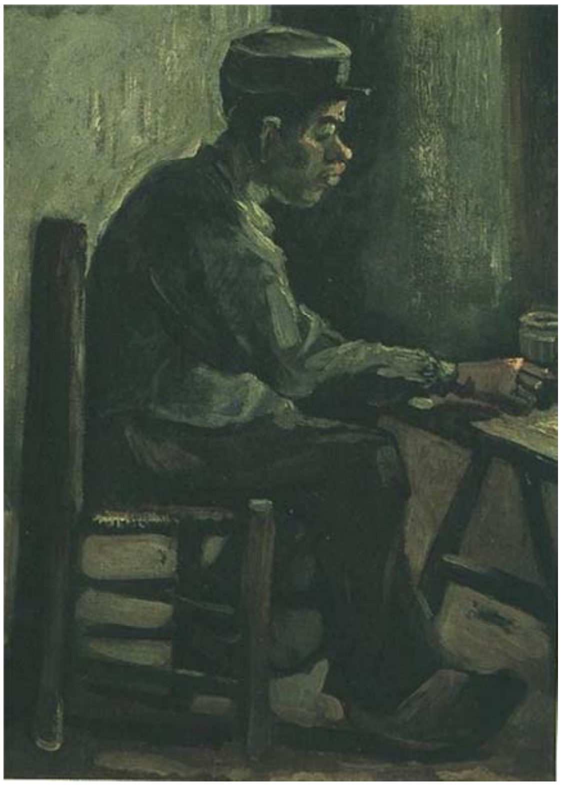

Figure 23: Peasant Sitting at a Table (Van Gogh 1885) (www.vggallery.com)

Wooden shoes however, were seen in other parts of Northern Europe in various forms and with different names. *Sabots* in Brittany, a province in France, were used the longest until the beginning of the 20th century. Men and women had both working wooden shoes (fig. 24) and nicely decorated ones for going to church (De Boer-Olij 2002). Rumor also has it that when workers in a factory wanted to protest they threw their *sabots* into the machines to prevent them from functioning; thus the term "sabotage" (DeMello, 2009). Wooden shoes are also seen in Belgium, Denmark, Sweden, and Germany (De Boer-Olij 2002).

In the Netherlands during the time period of 1815-1920 men and women, irrelevant of class used to wear *klompen* on a near-daily basis reserving their buckle shoes for festivities or Sundays. This practice becomes more common after the 1840s and does not really change until the 1920s (de Leeuw 1992). As observed in Van Gogh's paintings, wooden shoes were not only worn for outside activities but for indoors as well (fig. 22), and even during relaxation (fig 23). Therefore, people endured the hard surface of the wooden sole during almost the entire day. The time period of Middenbeemster, therefore, fits nicely into this picture. The Alkmaar collection is also consistent with this trend, in spite of its different time period (late medieval); during which, however *klompen* were worn.

The widely spread use of wooden shoes certainly implies its practicality. Otherwise it would not have been adopted by such a wide geographic region. Brief inquiries were made by the author of this thesis, asking fellow students of Dutch origin, whether they were familiar with the wooden shoes, their practicality, and if any kind of discomfort was ever attributed to them. Students responded that in the certain regions of the Netheralnds, particularly in the North, people still wear *klompen* when outdoor activities are involved, such as tending the garden. Their practicality was the outcome of characteristics such as providing stability especially while moving on frozen surfaces and protecting the foot against cold weather. Additionally they are extremely durable. Furthermore, it was mentioned that *klompen* provided sufficient protection for the foot against severe impact, such as preventing damage from heavy fallen object or being kicked by an animal. There was even a picture of a Dutch archeologist of the 1950's excavating while wearing his *klompen.* However, it was also reported that in some cases the shoes could become extremely uncomfortable, being worn continuously for over half an hour while walking, by causing pain and stiffness. So could there be a price to pay for the widespread use of the *klompen*? It is suggested that an increase in OD lesions may be such a consequence.

Figure 24: Sculptured woman in the market place in Locronan
wears the typical work wooden shoe
with a bit rising tips and an instep strap.
(De Boer-Olij 2002, 63)

5. Conclusions

The Middenbeemster skeletal collection offers a unique opportunity to examine skeletons for pathological conditions visible on the bone such as Osteochondritis Dissecans (OD). The generally excellent preservation of the skeletons provides material that is relatively easy to examine and distinguish pathological lesions from taphonomical ones. Additionally, the overall completeness of most skeletons offers the opportunity of observing smaller bones such as skeletal elements of the foot that are less often retrieved from excavations. The foot is the weight bearer of the entire body, thus daily suffers the most stress, compared to other parts of the human skeleton. Therefore, the foot and ankle may be valuable for reconstructing past human behavior.

OD is a pathological condition of the synovial joints that is incompletely understood by modern medicine. Strenuous activity and trauma appears to be among the most probable causes for this condition. Skeletal analysis, of a 19th century rural society from Middenbeemster, the Netherlands, yields results supporting these etiologies. Results also suggest that it was the combination of both strenuous activity and trauma that resulted in a high frequency of OD, of 15.1%, occurring in the foot and not in the knee joint, as expected from modern clinical literature. This high rate appears anomalous if it is compared to the general population OD prevalence of 0.02%, or to previous research conducted on non-Dutch populations that yielded results of only 0.6% (Ponce 2010) and 0.2% (Bourbou 2010). Skeletal assemblages from the Netherlands had higher rates of OD with Alkmaar at 4.8% and Dordrecht at 3.5%, respectively. The aforementioned percentages are lower compared to the one from Middenbeemster however, they are based on individuals from a higher economic status and more urbanized society.

Therefore, the overall prevalence of OD in Dutch populations is high compared to the general one. The highest rate observed in Middenbeemster can be mainly attributed to the fact that the population was rural and agricultural. Thus, stress imposed on the foot could be high due to strenuous activity, from working in the field, and the frequent chance of trauma. Lindeboom *et al*. (2012) describes life, in the 19th century of rural societies in the Netherlands, being tough. Women worked in the fields beside their husbands. Children, older than four years old, were also assisting their parents in the fields (www.openluchtmuseum.nl).

Consequently, individuals would be exposed to the same stressful conditions, which would explain, to an extent, why no significant differences in the occurrence of OD were observed between sexes and different age categories. Furthermore, the fact that OD was observed on skeletal elements of the foot, with no significant difference between left and right side, or between the different bones of the foot, indicates that a factor in common for every individual might be responsible. Thus, the theory of wooden shoes, in conjunction with strenuous activity and trauma, was proposed as a possible cause for the high occurrence of OD in the foot, since their hard and inflexible surface would limit the natural freedom of the foot. Furthermore, the fact that wooden shoes were also worn by people belonging in a high socio-economic status (De Boer-Olij 2002; De Leeuw 1992), can explain the higher prevalence of OD in the Alkmaar and Dordrecht collections, compared to that of general population.

Concluding, this research is useful because it offers the opportunity to examine lesions, such as osteochondritic ones, on dry bone without interference of tissue, as it happens with radiographs on patients. Therefore, an original contribution is made to our knowledge about the past life-ways of rural societies such as the Middenbeemster, in the Netherlands.

6. Further Research

The different ways of pressure distribution on the ankle joint, in different positions, have been experimentally reconstructed on cadaveric low limbs and the results are consistent with the theory of trauma being the primary cause of OD in the ankle (Athanasiou *et al.* 1995; Bruns and Rosenbach 1990). However, these experiments do not deal with the occurrence of OD in other bones of the foot. The theory of wooden shoes and their impact on the skeletal elements of the foot was suggested to explain the distribution of OD observed in the sample of Middenbeemster.

Further research should be made to investigate the OD prevalence of the foot, in populations originating from other parts of Northern Europe, where clogs were also worn. Furthermore, the frequencies could be compared to the one of Middenbeemster to investigate the occurrence of OD on the foot and examine if it can be correlated to every-day activity of individuals living under different conditions. Consequently, populations from southern Europe should be examined for OD lesions and eventually compared to the northern ones. This would help in the better understanding of the impact of different footwear, in conjunction with the level of activity, on the skeletal elements of the foot. Consequently it would investigate the impact of wooden shoes in the populations of northern Europe. Furthermore, comparisons in modern populations should be made between those that engage in strenuous activity with an additional high risk of trauma such as athletes and dancers, to those who practice a more sedentary life.

Additionally, experiments should be conducted recreating the pressure distribution on the foot when women wear high heels shoes, often known to cause pain and stiffness. Another interesting study would be to examine people marginally affected by modernization that do not wear shoes at all or wear sandals.

Regarding the Middenbeemster collection once the connection of the archives is made to each individual, a unique paleopathological record will be created, where every skeleton's sex, age-at-death and even profession will be known. This will furtherly investigate the multiple factors that contribute to the occurrence of OD. For instance, consulting the archives for kinship of the affected individuals can illuminate the genetic predisposition in the development of OD. Even the factor of malnutrition can be evaluated to some extent, since individuals belonging in a lower economic status, as suggested by their profession, would have had access to a poor nutrition based diet. Finally, once the analysis of all the skeletons comprising the collection is complete, OD will be assessed for a significantly larger sample size of individuals, including the age category of the adolescents. This will elucidate further the occurrence of OD on the foot and how it can be correlated to strenuous activity. However, it should be reminded that better classification criteria of OD for the foot should be developed to avoid misdiagnosis of OD lesions. The well preserved skeletons of the Middenbeemster collection may contribute in this attempt.

In overall, research on both old and modern skeletal assemblages of known historical and socio-economic background, combined with knowledge from modern clinical luteratute, can contribute to the better understanding of the nature of Osteochondritis Dissecans.

7. Abstract

Osteochondritis Dissecans (OD) describes a pathological condition of the subchondral bone and surrounding cartilage of synovial joints, such as the knee, elbow and ankle. Clinical research has associated OD to vigorous and strenuous activity, as well as trauma, micro or repetitive, due to its high occurrence in athletes. Reports of OD in archaeological skeletal remains are few and the majority involves a small number of individuals. Most studies of archaeological populations have found low OD prevalence, usually under one percent. In contrast, analysis of the Middenbeemster skeletal sample from the Netherlands found that 14 out of 93 adult individuals (15.1%), including males and females from different age categories, had OD in either one or multiple joints. This high percentage, combined with the fact that Middenbeemster derives from a rural agricultural population, is strong support for the impact of physical activity on bone. Furthermore, people in an agricultural society, that combines extensive outdoor activity on an uneven surface, are more susceptible to trauma. Finally, the *klompen,* one of Netherlands' current national emblems, were commonly worn not only in the Netherlands but in other regions of Northern Europe as well. It is suggested that their hard and inflexible surface, apart from limiting the natural freedom of movement of the foot, could also impact the tarsals and metatarsals, in case of trauma. Repetition of trauma could result in injury to the bone and eventually the cartilage. All these factors combined could result in the high frequency of OD observed in the Middenbeemster sample. Therefore, it is proposed that OD is a useful marker to aid in reconstructing previous life practices and subsequently better classification criteria should be developed.

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8. Appendices

Appendix I:

Data forms and results

Data forms 1-5: Observed capitella, femoral condyles and tibiae of individuals 1-101

Data forms 6-10: Observed talus, naviculars and 1st metatarsophalangeal joints of individuals 1-101.

Table 4: List of used abbreviations

A	Absence of OD, skeletal element present	
P	Presence of OD, skeletal element present	
P?	Probable OD lesion	
M	Missing skeletal element	
n.o.	non-observable surface of skeletal element	
L	Left	
R	Right	
M	Male	
PM	Probable Male	
F	Female	
PF	Probable Female	
MT1	First metatarsal	Head of MT1 and base of 1st p.p. → First metatarsophalangeal joint (1st MTJ)
1st p.p.	First proximal foot phalange	

Data Form 1

NA	Skeleton ID	Sex	Age	Capitellum		Femoral Condyle				Tibia	
				L	R	L		R		L	R
						Medial	Lateral	Medial	Lateral		
1	MB11S045V0055	F	36-49	A	A	A	A	A	A	A	A
2	MB11S053V0290	F	36-49	n.o.	n.o.	A	A	A	A	A	A
3	MB11S059V0133	M	36-49	A	A	A	n.o.	A	A	A	A
4	MB11S064V0050	PM	26-35	n.o.	n.o.	A	A	A	A	n.o.	A
5	MB11S070V0067	M	>40	M	M	A	A	A	A	A	A
6	MB11S084V0113	F	>35	n.o.	n.o.	A	A	A	A	A	A
7	MB11S088V0094	F	26-35	A	A	A	A	A	A	A	A
8	MB11S092V0124	M	36-49	n.o.	A	A	A	A	A	A	A
9	MB11S121V0211	PF	36-49?	M	M	n.o.	n.o.	n.o.	n.o.	M	A
10	MB11S123V0182	?	15.5±1.5y	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.	n.o.
11	MB11S126V0184	PF	36-49	n.o.	n.o.	A	A	A	A	A	A
12	MB11S149V0280	PF	18-25	A	A	A	A	A	n.o.	A	A
13	MB11S151V0666	F	26-35	A	A	A	A	A	n.o.	A	A
14	MB11S158V0427	M	36-49	n.o.	A	A	A	A	A	A	A
15	MB11S162V0316	PM	40-50	n.o.	A	n.o.	n.o.	n.o.	n.o.	A	A
16	MB11S183V0311	F	26-35	n.o.	n.o.	A	A	A	A	A	A
17	MB11S198V0601	F	26-35	A	A	A	A	A	A	A	A
18	MB11S216V0233	F	36-49	A	A	A	A	A	n.o.	A	A
19	MB11S226V0282	M	18-25	A	A	A	A	A	A	A	A
20	MB11S229V0324	?	17±1y	A	A	A	A	A	A	A	A

Data Form 2

NA	Skeleton ID	Sex	Age	Capitellum		Femoral Condyle				Tibia	
				L	R	L		R		L	R
						Medial	Lateral	Medial	Lateral		
21	MB11S233S0304	M	>40	n.o.	A	A	A	A	A	P?	A
22	MB11S236V0335	M	18-25	A	A	A	A	A	A	A	A
23	MB11S238V0350	M	18-25	A	n.o.	M	M	M	M	M	M
24	MB11S239V0769	M	18-25	A	A	n.o.	n.o.	n.o.	n.o.	A	A
25	MB11S243V0381	F	36-49	n.o.	A	n.o.	n.o.	A	n.o.	n.o.	M
26	MB11S250V0402	M	50+	M	M	A	A	A	A	A	A
27	MB11S257V1006	M	36-49	A	n.o.	A	A	A	A	A	A
28	MB11S261V0422	M	50+	M	A	A	A	A	A	A	A
29	MB11S263V0445	M	36-49	A	A	A	A	A	A	A	A
30	MB11S270V1066	M	18-24	A	A	A	A	A	A	A	A
31	MB11S275V0526	?	15±1	A	A	A	A	A	A	A	A
32	MB11S278V0584	F	36-49	A	A	A	A	A	A	A	A
33	MB11S281V0542	PM	36-49	n.o.	M	A	A	A	A	A	A
34	MB11S285V0452	M	50+	A	A	A	A	A	A	A	A
35	MB11S290V0472	M	18-25	A	A	A	A	A	A	A	A
36	MB11S294V0487	F	50+	A	A	A	A	A	A	A	A
37	MB11S306V0561	M	26-35	n.o.	n.o.	n.o.	A	A	A	A	A
38	MB11S310V0550	M	26-35	A	A	n.o.	n.o.	A	n.o.	A	A
39	MB11S313V0926	M	36-49	A	A	A	A	A	A	A	A
40	MB11S317V0649	M	50+	n.o.	n.o.	A	A	A	A	A	P?

Data Form 3

NA	Skeleton ID	Sex	Age	Capitellum		Femoral Condyle				Tibia	
				L	R	L		R		L	R
						Medial	Lateral	Medial	Lateral		
41	MB11S325V0676	M	26-35	A	A	A	A	n.o.	n.o.	A	A
42	MB11S331V0735	F	50+	n.o.	n.o.	n.o.	n.o.	A	A	A	A
43	MB11S337V0714	M	50+	n.o.	n.o.	A	A	A	A	A	A
44	MB11S339V0728	F	>40	n.o.	n.o.	A	A	A	A	n.o.	n.o.
45	MB11S340V0724	?	17±1y	A	A	A	A	A	A	A	A
46	MB11S345V0757	F	36-49	A	A	n.o.	n.o.	n.o.	A	A	A
47	MB11S347V0741	M	50+	A	A	A	A	A	A	A	P?
48	MB11S350V0844	?	16±1	A	A	M	M	M	M	M	M
49	MB11S356V0864	PF	36-49	A	n.o.	A	A	A	A	A	A
50	MB11S358V0763	F	36-49	A	n.o.	n.o.	n.o.	n.o.	n.o.	A	A
51	MB11S360V0762	F	50+	A	A	A	A	A	A	n.o.	n.o.
52	MB11S368V0794	M	26-35	A	M	A	A	A	A	A	A
53	MB11S369V0886	F	26-35	n.o.	A	A	A	A	A	A	A
54	MB11S370V0806	F	26-35	A	A	A	A	A	A	A	A
55	MB11S371V0790	M	36-49	A	A	A	A	A	A	A	A
56	MB11S374V0861	M	50+	n.o.	A	A	A	A	A	A	A
57	MB11S379V0851	M	18-25	A	A	n.o.	n.o.	n.o.	n.o.	A	A
58	MB11S381V0824	M	>35	n.o.	n.o.	A	A	A	A	A	A
59	MB11S382V0818	F	36-49	A	A	A	n.o.	n.o.	n.o.	A	A
60	MB11S385V0874	F	18-25	M	M	A	n.o.	A	n.o.	M	M

Data Form 4

NA	Skeleton ID	Sex	Age	Capitellum		Femoral Condyle				Tibia	
				L	R	L		R		L	R
						Medial	Lateral	Medial	Lateral		
61	MB11S388V0952	F	18-25	A	A	A	A	A	A	A	A
62	MB11S390V0831	F	>39	A	A	n.o.	n.o.	n.o.	n.o.	A	n.o.
63	MB11S397V0842	PF	50+	n.o.	n.o.	A	A	A	A	A	A
64	MB11S401V0876	F	26-35	A	A	A	A	A	A	A	A
65	MB11S402V0907	M	36-49	A	A	A	A	A	A	A	A
66	MB11S404V1134	M	26-35	A	M	A	A	A	A	A	P?
67	MB11S405V0882	F	36-49	A	A	A	A	A	n.o.	A	A
68	MB11S411V0904	M	36-49	M	M	n.o.	n.o.	A	A	A	A
69	MB11S413V0896	F	36-49	A	A	n.o.	n.o.	A	A	n.o.	n.o.
70	MB11S420V0936	F	26-35	n.o.	n.o.	A	A	n.o.	n.o.	A	A
71	MB11S427V0938	M	26-35	A	A	A	A	A	A	A	A
72	MB11S430V0965	F	26-35	A	A	A	A	A	A	A	A
73	MB11S432V0981	M	26-35	A	A	A	A	A	A	A	A
74	MB11S435V0929	M	36-49	A	A	A	A	A	A	A	A
75	MB11S446V0944	?	16.5±1	A	A	A	A	A	A	A	A
76	MB11S453V0973	F	26-35	n.o.	n.o.	A	A	A	A	A	A
77	MB11S460V0971	?	16.5±36m	A	A	n.o.	n.o.	n.o.	n.o.	A	A
78	MB11S461V0990	PF	18-25	A	n.o.	n.o.	n.o.	A	n.o.	A	A
79	MB11S466V1010	F	36-49?	n.o.	n.o.	A	A	A	A	A	A
80	MB11S467V1022	M	26-35	A	A	A	A	A	A	A	A

Data Form 5

NA	Skeleton ID	Sex	Age	Capitellum		Femoral Condyle				Tibia	
				L	R	L		R		L	R
						Medial	Lateral	Medial	Lateral		
81	MB11S468V1009	F	36-49	A	A	A	A	A	A	A	A
82	MB11S473V1003	M	26-35	A	A	A	A	A	A	n.o.	A
83	MB11S476V1054	PF	36-49	A	n.o.	A	A	A	A	A	A
84	MB11S477V1030	M	>40	A	A	A	A	A	A	A	A
85	MB11S481V1046	F	26-35	A	A	A	A	A	A	A	A
86	MB11S482V1048	M	36-49	A	A	A	A	A	A	A	A
87	MB11S487V1096	F	26-35	A	A	A	A	A	A	A	A
88	MB11S488V1037	PF	36-49	A	A	A	A	A	A	A	A
89	MB11S495V1041	F	26-35	A	M	A	A	M	M	M	M
90	MB11S497V1059	M	26-35	n.o.	n.o.	A	A	A	A	A	A
91	MB11S498V1071	F	50+	A	A	A	A	A	A	A	A
92	MB11S501V1097	F	18-25	A	A	A	A	A	A	A	A
93	MB11S502V1062	M	18-25	A	A	A	A	A	A	A	A
94	MB11S504V1109	F	36-49	A	n.o.	A	A	A	A	F	F
95	MB11S505V1095	PM	18-25	n.o.	A	n.o.	n.o.	A	A	M	M
96	MB11S507V1093	?	15±12m	n.o.	n.o.	A	A	n.o.	n.o.	n.o.	n.o.
97	MB11S512V1005	F	36-49	A	n.o.	A	A	A	A	A	A
98	MB11S521V1150	PF	36-49	A	A	A	A	A	A	A	A
99	MB11S524V1120	M	36-49	A	A	A	A	A	A	A	A
100	MB11S525V1119	PM	50+	A	n.o.	A	A	A	A	n.o.	A
101	MB11S527V1053	F	26-35	A	A	A	A	A	A	A	A

Data Form 6

NA	Skeleton ID	Sex	Age (years)	Talus		Navicular		MT1		1st prox.phal.	
				L	R	L	R	L	R	L	R
1	MB11S045V0055	F	36-49	A	A	A	A	A	A	P	A
2	MB11S053V0290	F	36-49	A	A	A	A	A	A	P	M
3	MB11S059V0133	M	36-49	A	A	A	A	A	A	A	A
4	MB11S064V0050	PM	26-35	n.o.	A	n.o.	n.o.	n.o.	M	M	M
5	MB11S070V0067	M	>40	A	A	A	A	A	n.o.	A	M
6	MB11S084V0113	F	>35	A	M	A	A	A	A	A	A
7	MB11S088V0094	F	26-35	A	A	A	A	M	A	A	A
8	MB11S092V0124	M	36-49	A	A	A	A	A	A	A	A
9	MB11S121V0211	PF	36-49?	A	M	A	M	A	M	M	M
10	MB11S123V0182	?	15.5±1.5y	M	M	M	M	M	M	M	M
11	MB11S126V0184	PF	36-49	A	A	A	A	A	A	A	A
12	MB11S149V0280	PF	18-25	A	A	A	A	A	A	M	M
13	MB11S151V0666	F	26-35	A	A	A	A	A	A	A	M
14	MB11S158V0427	M	36-49	A	A	A	A	A	P	A	A
15	MB11S162V0316	PM	40-50	A	P	A	A	A	A	M	A
16	MB11S183V0311	F	26-35	A	A	A	A	A	A	A	A
17	MB11S198V0601	F	26-35	A	A	M	A	A	A	A	A
18	MB11S216V0233	F	36-49	A	A	A	A	A	A	A	A
19	MB11S226V0282	M	18-25	A	A	A	A	A	P?	M	M
20	MB11S229V0324	?	17±1y	A	A	A	A	A	A	A	M

Data Form 7

NA	Skeleton ID	Sex	Age (years)	Talus		Navicular		MT1		1st prox.phal	
				L	R	L	R	L	R	L	R
21	MB11S233S0304	M	>40	A	A	A	A	A	A	P	A
22	MB11S236V0335	M	18-25	A	A	A	A	A	A	A	A
23	MB11S238V0350	M	18-25	M	M	M	M	M	M	M	M
24	MB11S239V0769	M	18-25	A	A	A	A	A	A	A	A
25	MB11S243V0381	F	36-49	A	A	A	A	A	A	A	A
26	MB11S250V0402	M	50+	A	A	A	M	M	A	A	M
27	MB11S257V1006	M	36-49	M	M	M	M	M	M	M	M
28	MB11S261V0422	M	50+	A	A	A	A	A	A	A	M
29	MB11S263V0445	M	36-49	A	M	A	A	A	A	M	A
30	MB11S270V1066	M	18-24	A	M	A	M	A	A	M	A
31	MB11S275V0526	?	15±1	A	A	A	A	A	A	M	A
32	MB11S278V0584	F	36-49	A	A	A	A	A	A	A	A
33	MB11S281V0542	PM	36-49	A	A	A	M	M	M	A	M
34	MB11S285V0452	M	50+	A	A	M	A	A	A	A	M
35	MB11S290V0472	M	18-25	A	A	A	A	A	A	P	P
36	MB11S294V0487	F	50+	A	A	M	A	A	A	A	A
37	MB11S306V0561	M	26-35	A	A	A	A	A	A	A	M
38	MB11S310V0550	M	26-35	A	A	A	A	A	A	M	M
39	MB11S313V0926	M	36-49	A	A	M	n.o.	A	A	A	A
40	MB11S317V0649	M	50+	A	A	P	P	A	P	A	A

Data Form 8

NA	Skeleton ID	Sex	Age (years)	Talus		Navicular		MT1		1st prox.phal.	
				L	R	L	R	L	R	L	R
41	MB11S325V0676	M	26-35	A	A	A	A	A	A	A	A
42	MB11S331V0735	F	50+	n.o.	A	M	n.o.	A	A	M	M
43	MB11S337V0714	M	50+	P	A	A	A	A	A	A	A
44	MB11S339V0728	F	>40	A	n.o.	A	A	M	A	M	M
45	MB11S340V0724	?	17±1y	A	A	A	A	M	A	A	A
46	MB11S345V0757	F	36-49	A	A	M	A	A	A	A	A
47	MB11S347V0741	M	50+	A	A	A	A	A	A	A	P
48	MB11S350V0844	?	16±1	M	M	M	M	M	M	M	M
49	MB11S356V0864	PF	36-49	A	A	A	A	A	A	P	P
50	MB11S358V0763	F	36-49	M	A	M	A	A	A	A	A
51	MB11S360V0762	F	50+	n.o.	A	M	M	M	M	M	M
52	MB11S368V0794	M	26-35	A	A	A	M	A	A	A	M
53	MB11S369V0886	F	26-35	A	M	A	M	A	M	A	M
54	MB11S370V0806	F	26-35	A	A	A	A	A	A	A	P
55	MB11S371V0790	M	36-49	A	A	A	A	A	A	A	A
56	MB11S374V0861	M	50+	A	A	A	A	A	A	M	M
57	MB11S379V0851	M	18-25	A	A	A	A	P	P	A	A
58	MB11S381V0824	M	>35	A	A	A	A	A	A	A	A
59	MB11S382V0818	F	36-49	A	A	M	A	A	n.o.	A	A
60	MB11S385V0874	F	18-25	M	M	M	M	A	M	A	A

Data Form 9

NA	Skeleton ID	Sex	Age (years)	Talus		Navicular		MT1		1st prox.phal.	
				L	R	L	R	L	R	L	R
61	MB11S388V0952	F	18-25	A	A	A	A	A	A	A	A
62	MB11S390V0831	F	>39	A	n.o.	A	A	A	A	A	A
63	MB11S397V0842	PF	50+	A	A	A	A	A	A	A	A
64	MB11S401V0876	F	26-35	A	A	A	A	A	A	A	A
65	MB11S402V0907	M	36-49	A	A	A	A	A	A	A	A
66	MB11S404V1134	M	26-35	A	M	A	M	M	A	M	A
67	MB11S405V0882	F	36-49	M	M	M	M	M	A	M	M
68	MB11S411V0904	M	36-49	A	A	A	M	P	P	M	A
69	MB11S413V0896	F	36-49	A	n.o.	A	n.o.	n.o.	M	M	M
70	MB11S420V0936	F	26-35	P	A	A	A	A	A	A	A
71	MB11S427V0938	M	26-35	A	A	A	A	A	A	A	A
72	MB11S430V0965	F	26-35	A	A	A	A	A	A	M	A
73	MB11S432V0981	M	26-35	A	M	M	M	M	M	M	M
74	MB11S435V0929	M	36-49	A	A	A	M	A	M	A	A
75	MB11S446V0944	?	16.5±1	P	A	A	A	A	A	A	A
76	MB11S453V0973	F	26-35	A	A	A	A	A	A	A	A
77	MB11S460V0971	?	16.5±36m	A	A	A	M	A	A	A	A
78	MB11S461V0990	PF	18-25	A	A	A	A	M	M	M	M
79	MB11S466V1010	F	36-49?	A	A	M	A	M	A	A	A
80	MB11S467V1022	M	26-35	A	A	A	A	A	A	A	A

<u>**Data Form 10**</u>

NA	Skeleton ID	Sex	Age (years)	Talus		Navicular		MT1		1st prox.phal.	
				L	R	L	R	L	R	L	R
81	MB11S468V1009	F	36-49	M	A	M	M	A	A	A	A
82	MB11S473V1003	M	26-35	A	A	A	A	A	A	A	A
83	MB11S476V1054	PF	36-49	A	A	A	A	A	A	A	A
84	MB11S477V1030	M	>40	A	A	A	A	A	A	M	A
85	MB11S481V1046	F	26-35	A	A	M	M	A	A	A	A
86	MB11S482V1048	M	36-49	A	A	A	A	A	A	A	M
87	MB11S487V1096	F	26-35	A	A	A	A	A	A	A	A
88	MB11S488V1037	PF	36-49	A	A	M	M	A	A	M	A
89	MB11S495V1041	F	26-35	M	M	M	M	M	M	M	M
90	MB11S497V1059	M	26-35	A	A	A	A	A	A	A	A
91	MB11S498V1071	F	50+	A	A	A	A	A	A	M	M
92	MB11S501V1097	F	18-25	A	M	A	M	A	A	A	A
93	MB11S502V1062	M	18-25	A	A	A	A	A	A	A	A
94	MB11S504V1109	F	36-49	A	A	A	M	A	A	M	A
95	MB11S505V1095	PM	18-25	M	M	M	M	M	M	M	M
96	MB11S507V1093	?	15±12m	M	M	A	M	M	M	M	M
97	MB11S512V1005	F	36-49	A	A	M	M	M	M	M	M
98	MB11S521V1150	PF	36-49	M	M	M	A	A	M	A	M
99	MB11S524V1120	M	36-49	A	A	A	M	A	A	M	A
100	MB11S525V1119	PM	50+	A	A	A	M	A	A	A	M
101	MB11S527V1053	F	26-35	A	A	A	A	A	A	M	A

Affected Individuals

Males

Skeleton ID	Age (years)	OD	Affected skeletal element(s)	Size of lesion (mm)	Symptoms of Osteoarthritis
MB11S158V0427	36-49	P	Right MT1: head	2	Slight lipping on proximal phalange
MB11S162V0316	40-50	P	Right Talus: posterior subtalar facet	10	Marginal lipping, eburnation
		P?	Glenoid cavities bilaterally	Left:7 Right:5	porosity
MB11S226V0282	18-25	Lesion, where OD would occur but could also be taphonomic	Right MT1: head	2	-
MB11S233S0304	>40	P?	Left Tibia: distal end	6	-
		P	Left 1st proximal foot phalange: base	3	-
MB11S270V1066	18-25	P?	Right glenoid cavity	2	-
MB11S290V0472	18-25	P	1st proximal foot phalange bilaterally: base	Left:0,5 Right:1	-
MB11S317V0649	50+	P?	Right tibia: distal end	2	-
		P	Naviculars: proximal articular facet	Left:9 Right:2	-
		P	Right MT1: base	4	-
MB11S337V0714	50+	P	Left Talus: posterior subtalar facet	5	Slight lipping

MB11S347V0741	50+	P?	Right Tibia: distal end	6	-
		P	Right 1st proximal foot phalange	1	Mild marginal lipping and erosion of bone surface.
MB11S368V0794	26-35	P?	L5: Right inferior articular facet	4	-
MB11S379V0851	18-25	P	MT1 bilaterally: head	Left:4 Right:2	-
MB11S404V1134	26-35	Depression	Tibia: distal end	7	-
MB11S411V0904	36-49	P	MT1 bilaterally: base	Left:1 Right:0,5	-
MB11S473V1003	26-35	P?	Left glenoid cavity	2	-

Females

Skeleton ID	Age (years)	OD	Affected skeletal element(s)	Size of lesion (mm)	Symptoms of Osteoarthritis
MB11S045V0055	36-49	P	Left 1st proximal foot phalange: base	4	Marginal lipping
MB11S053V0290	36-49	P	Left 1st proximal foot phalange: base	2 probably healing phase	-
MB11S149V0280	18-25	P?	Right glenoid cavity	6,5	Porosity and new bone formation
MB11S356V0864	36-49	P	1st proximal foot phalange bilaterally: base	Left: 1 Right: 1	Lipping and eburnation on both, more pronounce on the left
MB11S370V0806	26-35	P	Right 1st proximal phalange: base	1	-
MB11S420V0936	26-35	P	Left talus: Posterior subtalar facet	6	Margins of lesion smoothened and slight eburnation present

Adolescent

Skeleton ID	Age (years)	OD	Affected skeletal element(s)	Size of lesion (mm)	Symptoms of Osteoarthritis
MB11S446V0944	16.5±1	P	Left talus: posterior subtalar facet	10	-

Appendix II:

Photographs of affected individuals, definite and probable cases

Males

MB11S158V0427 36-49 years old

OD of the head of the right MT1. Lesion size: 2.0 mm

MB11S162V0316 40-50 years old

OD on the posterior subtalar facet of the right talus. Lesion size: 10 mm. Marginal lipping and eburnation present

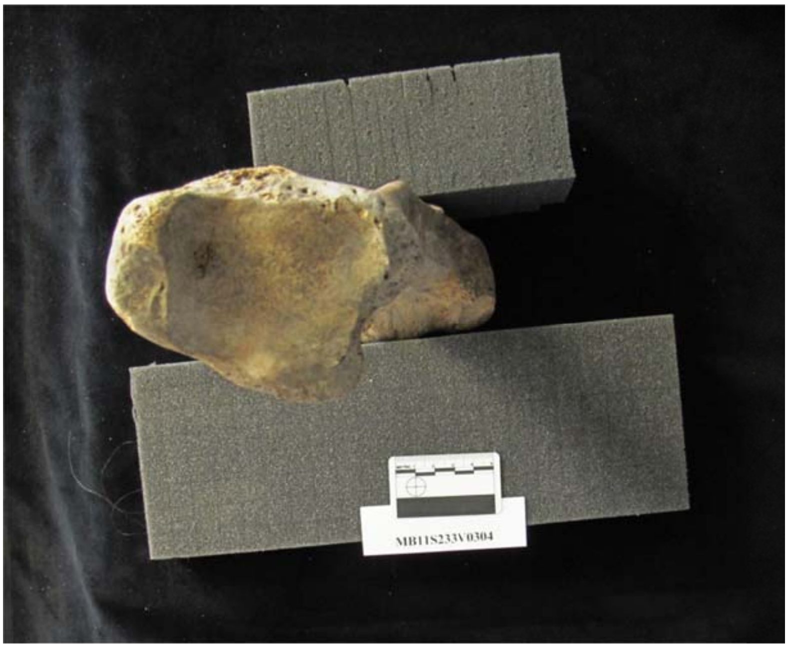
MB11S162V0316 40-50 years old

Probable OD. Bilateral porosity in the center of the glenoid cavities. Lesion size: 7.0 mm in the left glenoid cavity and 5.0 mm in the right glenoid cavity

MB11S226V0282 18-25 years old

Lesion, 2.0 mm, observed in the center of the head of the right MT1, where OD is expected to occur. However, the trabecular is damaged and the observed pit appears to penetrate deep into the bone surface; therefore the lesion could also be a result of taphonomic process.

MB11S233V0304 >40 years old



Probable OD lesion at the distal end, medial side of the right tibia.
Lesion size: 6.0 mm

MB11S233V0304 >40 years old

OD on the base of the 1st proximal phalange of the left foot. Lesion size: 3.0 mm
Note the slight erosion of the bone surface.

MB11S270V1066 18-25 years old

Probable OD lesion of the glenoid cavity of the right scapula. Lesion size 2.0 mm. This individual suffered from tuberculosis. His tarsals and metatarsals did not bear osteochondritic lesions and a depression observed on the anterior-inferior surface of the left lateral femoral condyle is attributed to taphonomic processes. Considering his severe kyphosis, the shoulder joint would have undergone extra pressure when the individual would lift weight, therefore being more prone to developing OD of the glenoid cavity of the scapula.

MB11S290V0472 18-25 years old

Bilateral OD occurrence on the base of the 1st proximal foot phalanges.
Lesion size left: 0.5 mm. Lesion size right: 1.0 mm

MB11S317V0649 50+ years old

Bilateral OD occurrence on the proximal articular surface of the naviculars.
Lesion size left: 9.0 mm. Lesion size right: 2.0 mm

MB11S317V0649 50+ years old

OD lesion on the base of the right MT1. Lesion size: 4.0 mm

MB11S317V0649 50+ years old

Probable OD lesion in the medial side of the distal end of the right tibia.
Lesion size: 2.0 mm

MB11S337V0714 50+ years old

OD of the posterior subtalar facet of the left talus. Lesion size: 5.0 mm
Slight marginal lipping on the medial side of the posterior subtalar facet.

MB11S347V0741 50+ years old

OD on the base of the 1st proximal phalange of the right foot.
Lesion size:1.0 mm.
Note the marginal lipping and the erosion of the bone surface indicative of secondary OA.

MB11S347V0741 50+ years old

Probable OD lesion in the medial side of the distal end of the right tibia.
Lesion size: 6.0 mm.
Note that a depression is also visible in the medial side of the distal end of the left tibia. But its relative small size, 1.0 mm, and the lack of knowledge and classification criteria considering the development of OD in the distal end of the tibia, excludes this case even as a probable one.

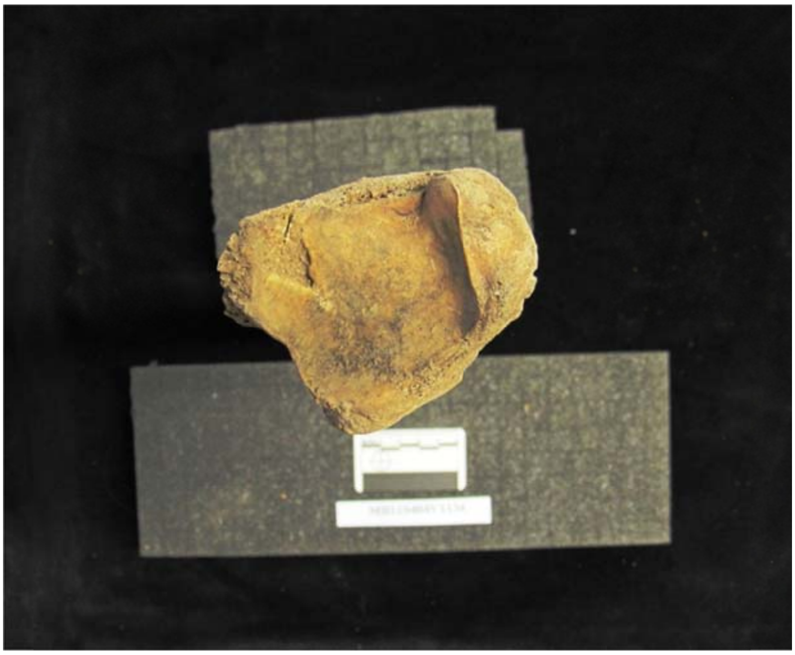
MB11S368V0794 26-35 years old

Probable OD of the right inferior articular facet of the L5. Lesion size: 4.0 mm. No case of OD has been mentioned so far in clinical literature. However the fact that the L5 suffers the most pressure, due to body weight, compared to the rest vertebrae of the spine indicates that OD could occur in that location. The joint is regarded synovial and the characteristics of the lesion fit the description of OD.

MB11S379V0851 18-25 years old

Bilateral case of OD on the head of the MT1.
Lesion size right: 2.0 mm. Lesion size left: 4.0 mm.
Slight marginal lipping was observed on both 1st proximal foot phalanges

MB11S404V1134 26-35 years old



Lesion on the lateral side of the distal end of the right tibia. Lesion size 7.0 mm. The margins of the tibia are not well preserved. Additionally the depression does not exhibit the typical characteristics of OD (i.e. crater shape, exposed trabecular). Finally, the individual was missing the right talus and navicular, which could be used to investigate whether the foot suffered an impact. Therefore final assessment regarding the etiology of the observed depression in the tibia could not be made. There is a possibility it could be taphonomical.

MB11S411V0904 39-49 years old

Bilateral OD on the base of the MT1.
Lesion size left:1.0 mm. Lesion size right: 0.5 mm

MB11S473V1003 26-35 years old

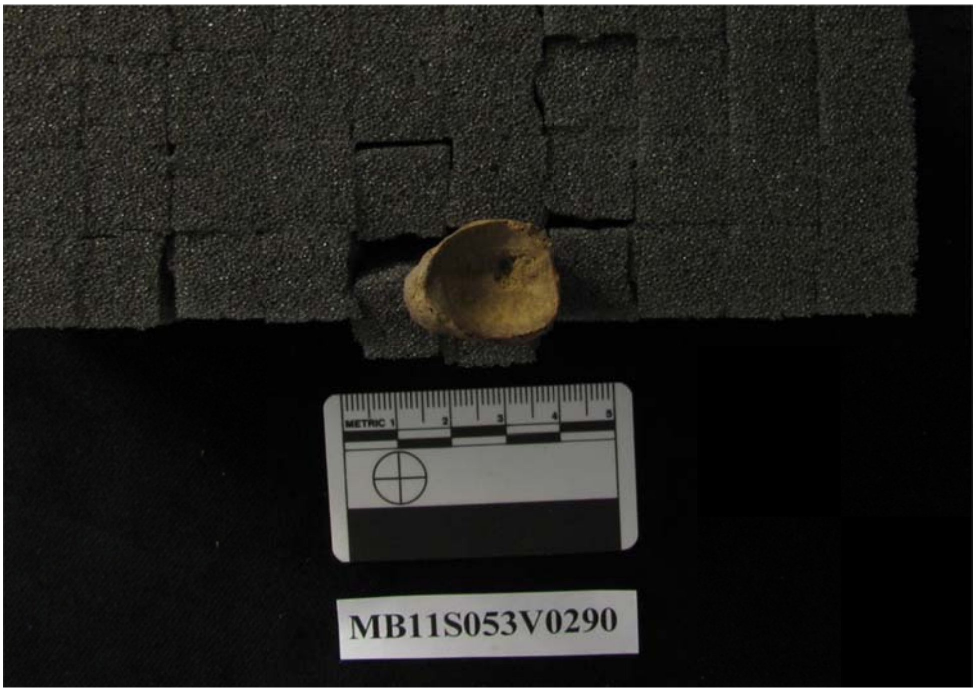
Probable OD of the glenoid cavity of the right scapula.
Lesion size: 2.0 mm

Females

MB11S045V0055 36-49 years old

OD on the base of the 1st proximal phalange of the left foot. Lesion size: 4.0 mm.
Note the exposed trabecular and the marginal lipping.

MB11S053V0290 36-49 years old

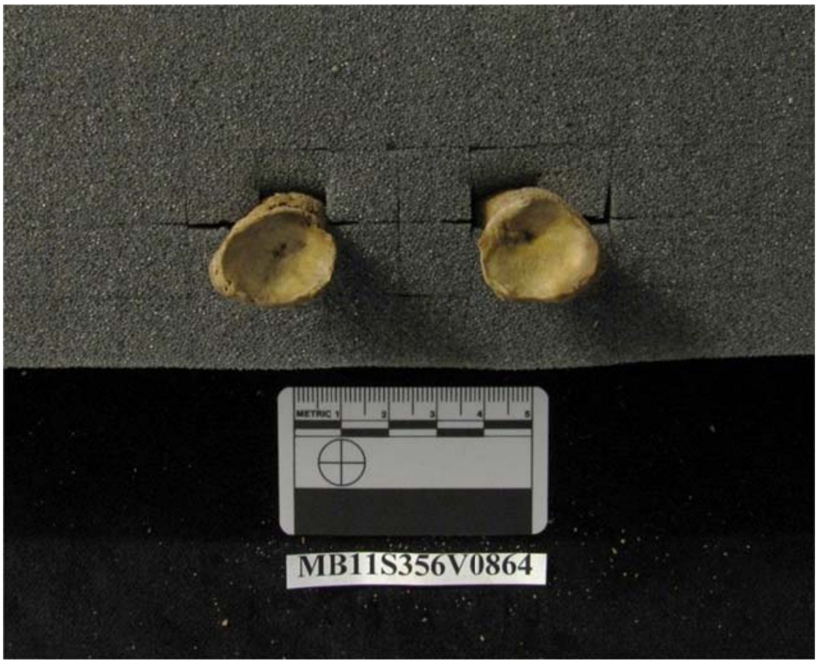


OD on the base of the 1st proximal phalange of the left foot. Lesion size: 2.0 mm. There appears to be bone remodeling and the lesion shows signs of healing.

MB11S149V0280 18-25 years old

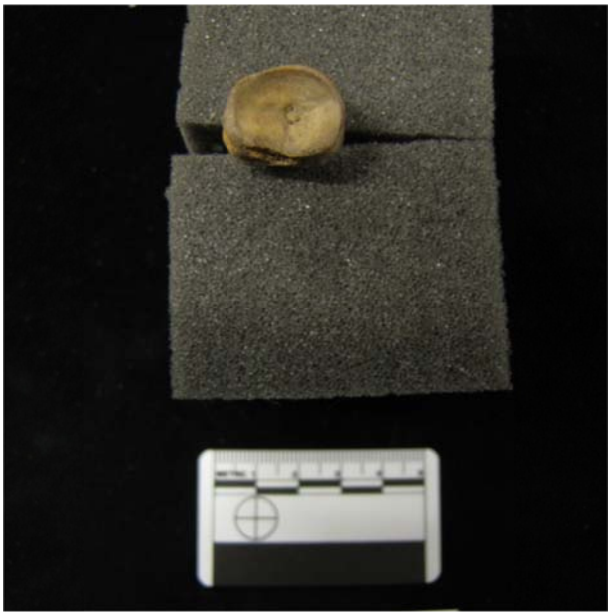
Probable OD of the glenoid cavity of the right scapula. Lesion size: 6.5 mm. Note the erosion and porosity of the surface. Indicating symptoms of secondary OA. The lesion appears to be in a healing phase due to new bone formation.

MB11S356V0864 36-49 years old



Bilateral OD on the base of the 1st proximal foot phalanges.
Lesion size on the left: 1.0 mm.
Lesion size on the right: 1.0 mm.
Lipping and eburnation on both phalanges. More pronounce on the left. Indicating presence of secondary OA.

MB11S370V0806 26-35 years old



OD on the base of the 1st proximal phalange of the right foot.
Lesion size: 1.0 mm.
New bone formation in the center. Shows signs of healing.

MB11S420V0936 26-35 years old

OD in the posterior subtaral articular facet of the left talus. Lesion size: 6.0 mm. The margins of the lesions are smoothened and there is slight eburnation present, indicative of development of secondary OA.

Adolescent

MB11S446V0944 16,5±1 year, years old

OD in the posterior subtalar articular facet of the left talus. Lesion size: 9.0 mm