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Preface

This thesis is written as completion to the Master of Science in Human Osteoarchaeology and Funerary Archaeology at the Faculty of Archaeology, Leiden University. This master focuses on the study of human bones and teeth in both archaeological and physical anthropological contexts, and soon it became a true passion. The subject of this thesis, skeletal cranial and post-cranial non-metric traits, was one of the first topics I came into contact with after I started studying human osteology, and it sparked my interest. After some research I found out that there are actually different categories of non-metric traits, whereas practically no study actually employs this distinction, but rather lumps them together. This is something that has bothered me from the day I learned about non-metric traits, so it was no surprise that this became the starting point for my thesis.

~The process of scientific discovery is, in effect, a continual flight from wonder~

Albert Einstein

Acknowledgements

This research project would not have been possible without the support of my supervisors, friends, and family.

First and foremost I would like to express my appreciation and gratitude to my supervisor, teacher, and inspiration Dr. Andrea Waters-Rist, for her invaluable help and constructive suggestions during the development, research, and writing of this thesis. I thank her for all the time and effort she has spent on me, and her patient answers to my never-ending questions. I also want to express my appreciation and gratitude to Dr. Menno Hoogland, who was always able to provide much-needed encouragement and never seemed to lose faith in me.

The discussions and conversations with Simone Lemmers, RMA, and Rachel Schats, RMA, helped me to get on the right track. I also would like to thank Rachel for the numerous times she let me use her library. Simone's kind support and occasional cuddle helped me through hard times. Thanks to Frank van Spelde for helping me drag boxes of skeletons from the basement to the lab and back again, his help with the creation of the invaluable Middenbeemster database, and letting me assist during DNA sampling.

Furthermore I would like to express my thanks to the following friends and classmates for their support, advice, and understanding for my stressed moods during the completion of this research: Dafne Koutamanis, Jorinde Vroeijenstijn, and Sasha Ahoud. Thanks to Jordy Aal for lending me a useful syllabus on statistical analyses. Thanks to my classmates Sonja Jäger and Barbara Veselka for their helpful insights, and to Tristan Krap for his clear explanations and help when I experienced some starting problems. *Paldies* to Kārlis Briedis for his help with the creation of the frontpage, being my external reader, and overall kind support. Thanks to dr. Mike Groen for providing me with an amount of starting literature and sharing his knowledge on non-metric traits.

Despite not being directly involved in this research, I am indebted to prof. dr. Simon Hillson, prof. dr. Tony Waldron and dr. Carolyn Rando

of the Faculty of Archaeology at the University College London, who so generously shared their incredible knowledge and have been a true inspiration.

I would especially like to express my heartfelt gratitude and love to Robert, who never ceased to believe in me. He supported and encouraged me throughout the entire process, and comforted me during tough times. His comments after being the first to proofread my thesis, proved very valuable. I could not have done it without him.

Finally, I would like to thank my beloved parents Theo and Treeske, who have always believed in me and were always there to support and enhearten me during my academic career.

CHAPTER 1. INTRODUCTION

1.1. Introduction to Osteoarchaeology

Human osteology is the scientific study of human bones in all its facets. Under the name osteoarchaeology it has long been an integral part of archaeology. It is not surprising that human bones have provoked much interest and have been subjected to a wide array of research: human bone material provides us with a direct and personal link to people in the past and many aspects of their daily lives. The fact that bone material is often recovered from the archaeological record due to its durable composition makes it an interesting material with lots of potential. Besides the basal estimations of sex, age, and stature, the analysis of human bone can contribute significantly to our understanding of pathology, activity, diet, genetics, and overall development of a population in a biocultural context. Research on bone ranges from macroscopic, morphological observations to microscopic research. Also, in recent years, the chemical appraisal of human bones has progressed into a fully mature field of research.

In this thesis, macroscopic observations of morphological features of the skeleton, so-called "non-metric traits" will be examined to contribute to the debate about the value of non-metric traits in archaeological research. In this thesis *non-metric trait(s)* will be abbreviated to *NMT(s)*.

In current osteological research no distinctions are made with regard to NMTs. Despite clear differences in cause, the different categories of NMTs –genetic and mechanical- are lumped together. For a basic skeletal report or research that is not directly concerned with this topic, the use of different NMT categories is not necessarily of added value. However, for specific studies, the employment of different categories of NMTs can certainly provide valuable insights for the research. Beside the fact that the observation of NMTs, even on fragmented or damaged

skeletal material, is an easy and inexpensive method, NMTs can also supply a refreshing view on the daily life of past people. Mechanical NMTs are clear and easily observed skeletal markers when one wants to study the influence of habitual physical activities. A deeper understanding of mechanical NMTs can provide insight in the occupational activities of the individuals under study. The study of genetic NMTs can contribute to the establishment of genetic relatedness and familial bonds within a population or assemblage, especially when the retrieval of DNA is not possible due to poor preservation of the material.

1.2. Theory

NMTs have a long history and have been known to anatomists for several millennia. Over 2000 years ago, the Greek scholar Hippocrates noted minor skeletal variation between individuals, while observing Wormian bones in human cranial sutures (White *et al.* 2011). In 1670 AD, the Dutch anatomist Kerkring described anatomical variants in his study of the morphology of the human skull (Tyrrell 2000). Almost 300 years later, in the 1950s, the German geneticist Hans Grüneberg was the first to understand the developmental and genetic basis of these skeletal variants, in his study of inheritance patterns in crossbred mice. He thought that the part of the genome that is responsible for NMTs was likely to be polymorphic (i.e. has multiple forms) and polygenic (i.e. multiple genes). Grüneberg also named the term "*quasi-continuous*", after he noted that third molars in mice did not necessarily erupt: there is a continuous genetic basis for a certain trait (in this case the third molar), but its expression is discontinuous (the molar is either absent or present) (Tyrrell 2000). A decade later, Douglas Falconer developed the concept of a developmental threshold, which encompassed that the distribution of NMTs was the result of an individual's inherited tendency to develop a trait, in combination with the factors that occur throughout the individual's ontogeny, that make them more or less likely to develop a certain trait (Falconer 1965). Falconer assumed that these ontogenic factors

were normally distributed over a population: the point after which all individuals in the population would show a trait was named the "*population threshold*" (Falconer 1965, 53). During the later 1960s, the study of NMTs saw a renewed interest, in part inspired by the influential paper "*Epigenetic Variants in the Human Cranium*" by Robert and Caroline Berry (1965). At the time of publishing, the thought was that the frequency of NMTs could provide insight in the relationship between contemporaneous and temporally distinct human populations. Since genetic studies were still in their infancy, this invoked much enthusiasm (Tyrrell 2000). The Berry's described NMTs as being an expression of developmental genes (Berry and Berry 1965). They purposely used the term "*epigenetic*", to emphasise the likelihood of modification during development. They stressed that they did not find a relationship between a specific gene and a specific NMT (Berry and Berry 1965). After the 1970s, the non-metric revival quickly diminished, although several important articles were still published. While NMT research is not a major focus in bioarchaeology, it has always been present. Nowadays, research using NMTs is increasing again. Our growing knowledge about the aetiology and development of numerous NMTs has led researchers to a revised approach. In current research, skeletal NMTs are only infrequently applied to establish genetic relatedness, since DNA research is the preferred method for this. Dental NMTs are still used fairly often, because of their strong genetic component. As I will attempt to concretise in this thesis, further research will aid in clarifying the complex and sometimes poorly understood aetiology of NMTs. Especially mechanical NMTs have potential to deliver insight about the effect of habitual physical activities on the skeleton.

1.3. Non-Metric Traits: Definition, Variation and Paradoxes

NMTs are minor morphological variations of phenotypic expression, that occur in all body tissues, known under a range of other names, such as discontinuous traits (Brothwell 1972), discrete traits (Corruccini 1976),

minor/epigenetic variants (Berry and Berry 1976), or even all-or-none attributes (Cavalli-Sforza and Bodmer 1971). For most archaeological purposes, only skeletal and dental NMTs are relevant. Skeletal and dental NMTs are expressions of the variation observed in bones and teeth, in the form of differently shaped cusps, roots, tubercles, processes, crests, foramina, articular facets, and a range of other features (White *et al.* 2011). Over 400 NMTs have been recognised in the human skeleton. As they are highly heterogeneous, an underlying classification is useful in order to illustrate and understand the wide range of variation one may encounter while examining NMTs:

- Variation in the number of bones. The average adult skeleton consists of 206 bones. However, some individuals may have more or fewer skeletal elements, for example a supernumerary thoracic rib (Mays 2010).
- Anomalies of bone fusion. Certain skeletal elements may fail to fuse, such as the metopic suture, or skeletal elements that are usually separate, may fuse, such as the vertebrae (Mays 2010).
- Variation in bony foramina. A foramen is a perforation in the bone that usually serves to convey nerves or blood vessels. A wide variation in size, number, and location of foramina is known, for example the supraorbital foramen (Mays 2010).
- Articular facet variation. Articular facets usually occur at the site of a joint. Variation in the form, size, or location of articular facets may occur, such as a tibial squatting facet at a site where usually no facet occurs.
- Hyperostosis. Hyperostotic traits are characterised by excess bone formation into, or in response to soft tissue, for example a mylohyoid bridge (Mays 2010).
- Hypostosis. Hypostotic traits are characterised by incomplete or arrested development within, or between bones, for example the vastus notch on the patella (Mays 2010).

The division in hyper- and hypostotic traits was put forward by Nancy Ossenberg in her 1969 PhD thesis, and has been essential for the basal understanding of NMTs, because this dichotomy forms the basis for the categorisation and understanding of the development of NMTs.

NMTs normally do not cause medical symptoms and will go largely unnoticed, although some NMTs are palpable during life (e.g. palatine torus) or can be recorded on X-rays or other medical scans (e.g. sternal foramen) (Mays 2010). However, one can imagine that a sacralised fifth lumbar vertebra (L5) can cause discomfort. Particularly unilateral sacralisation of L5 may lead to curvature or rotation of the lumbar spine, which in exchange can lead to progressive scoliosis, lower back pain, and sciatica (Barnes 1994). Hauser and De Stefano (1989) emphasise that NMTs can have medical relevance. The presence of particular variants may aid in making a diagnosis. For instance, the occurrence of numerous sutural ossicles can be a symptom of cleidocranial dyostosis. The presence of many hypostotic traits is often noted in individuals with overall physical arrested development (Hauser and De Stefano 1989).

NMTs are often scored using a dichotomous (present/absent), or multilevel system (e.g. small/medium/large). The latter system is potentially very useful, since it provides increased levels of information. On the other hand, using a multiple level scoring system can be a complicating factor during statistical analysis, for instance when one has to decide whether to include a partial atlas bridge in the statistical analysis as present or absent. Despite their name, NMTs are rarely really discrete or discontinuous: Mizoguchi (1985) suggested that the expression of many traits is actually quantifiable (Mizoguchi 1985). Currently, the osteological field has not yet been able to widely utilise this in relevant studies.

A common complaint about NMTs is the lack of clear recording and scoring standards, and definitions (Tyrrell 2000). NMTs have proven complex to measure as a continuous variable. Due to the wide range of variability between traits, a standardised recording or scoring system has not yet been formed. Despite the elaborate and descriptive nature of

different systems, individualised recording and scoring systems per specific trait still seem the most useful. Notwithstanding the variety in recording and scoring systems, some systems are widely used and, for lack of something better, could be considered a standard system. A widely used system is the recording and scoring system by Hauser and DeStefano (1989). Although the authors only focus on cranial NMTs, the cautious descriptions for each trait in their 1989 book "*Epigenetic Variants of the Human Skull*" are a valuable contribution to reliable recording and scoring (Hauser and DeStefano 1989). Finnegan (1978) has provided a valued system as well, accompanied by clear, descriptive figures of each trait. Contrary to Hauser and DeStefano, he includes both cranial and post-cranial traits, with a simple yet adequate recording and scoring system (Finnegan 1978).

NMTs have frequently been used to estimate ancestry and biodistance (similarity between skeletal populations), by quantifying the amount of NMTs as a measure for genetic relatedness. These studies were performed under the assumption that NMTs are genetically inherited (Alt *et al.* 1997). However, their polymorphic nature in combination with growing incertitude about the influence of environmental factors has made researchers more cautious in their conclusions about biodistance. One has to be careful not to prematurely suggest the presence of familial relatedness when similar NMTs are recorded, without consideration of other factors, such as environment. Tyrrell (2000) even goes as far as to call NMTs completely unsuitable as measures for biodistance studies. NMTs do not necessarily have a strictly genetic or environmental character: some traits are in large part caused by continuous mechanical stress or repeated activities, for example the third trochanter on the femur, which functions as an extra site of attachment for the gluteus maximus muscle. It is now clear that most or even all NMTs have a multifactorial nature. No known NMT has a solely genetic or mechanical (environmental) cause. Despite the multifactorial cause of most NMTs, in this thesis I will employ a genetic category and a mechanical category. Traits will be classified into a

category if its cause is mainly genetic or mechanical. For some NMTs the background was either not clear or not predominately genetic or mechanical. This led me to create the ambiguous category, which contains NMTs that have an ambiguous cause or whose cause is at this moment too uncertain.

1.4. Intrapopulational Non-Metric Variation

NMTs have shown a wide range of variation within populations, at both the inter-individual and intra-individual level (Hauser and DeStefano 1989). When studying NMTs, one has to take the influence of a range of internal and external factors into consideration:

Sexual dimorphism encompasses the differences between males and females in the incidence and/or expression of a certain trait. Results obtained from both anthropological research and clinical literature generally show no or little sexual dimorphism in NMTs (Hauser and DeStefano 1989). Hauser and DeStefano (1989) mention that one would expect a parallel trend in the two sexes, i.e. that NMTs would occur at an equal rate in males and females. If this parallel trend does not occur, the trait may be sexually dimorphic, i.e. differently influenced in both sexes (Hauser and DeStefano 1989). Berry (1975, 529) stated that "…[a] lack of consistency of sex dimorphism observed for many of these traits confirms the idea that they are the outward manifestation of the activity of genetic, epigenetic, and even overtly environmental forces..."

Age-related changes are differences between age groups in the incidence and/or expression of a certain trait. Although it has been suggested that age affects the incidence of certain NMTs, no convincing results have been obtained (Hauser and DeStefano 1989). Age however, can influence the visibility of traits, although most NMTs are probably relatively resistant against the process of ageing. Buikstra (1972) emphasised the importance of the age-progressive nature of many NMTs. She argued that the progressive ossification that is involved in hyperostotic traits may continue throughout ontogeny. This supports

previous indications that hyperostotic traits are evident by early adolescence, even though the full expression may occur later in life (Buikstra 1972).

Symmetrical manifestation is the tendency of a trait to occur on both sides of the body (bilaterality). In a bilaterally symmetrical organism one would expect a tendency towards a bilateral occurrence of NMTs. Perizonius (1979, 102) called this "a preference for symmetrical occurrence". However, numerous studies have shown that NMTs do not always follow the expected path of symmetrical expression, depending on the origin of the sample under study, and the specific trait (Hauser and De Stefano 1989). Unilateral NMTs aside, certain NMTs have a greater tendency towards bilateral expression, such as the mastoid foramen. Since mechanical NMTs are the result of habitual activities, this means that the expression of a trait is also influenced by the mechanical nature of the physical activity. For instance, tibial squatting facets tend to be bilateral, since squatting is usually done with both ankles bent, whereas other NMTs, such as an os acromiale, are usually caused by unilateral activity.

Laterality is the tendency of a unilateral trait to occur more often on a certain side. Several studies have yielded evidence for the lack of laterality, for example for the dominant hand to have a different frequency of a NMT (Hauser and De Stefano 1989). However, laterality cannot be excluded as factor that affects NMTs, since it is very well possible that unilateral NMTs follow an unpredictable laterality pattern.

Intertrait association is the tendency for the simultaneous occurrence of a number of different traits. Association between certain traits would be expected, for example between multiple sutural ossicles, or between a double condylar facet and a double atlas facet. Research into this topic has yielded inconsistent results. Ossenberg (1969) however, observed a notable correlation between a number of hypo- and hyperostotic traits, i.e. one hypo- or hyperostotic trait was strongly correlated with the co-occurrence of another hypo- or hyperostotic trait (Ossenberg 1969 in Hauser and De Stefano 1989). Some NMTs that derive from a common

fundamental process may be associated in their occurrence, whereas others are largely independent from one another.

Despite their shortcomings and complicating factors, NMTs have shown great use in the assessment of biodistance in ancient populations (e.g. Alt *et al.* 1997, Khudaverdyan 2012, Tyrrell 2000). NMTs have several major advantages. First, NMTs are inexpensive to record. Also, recognising and scoring the traits is relatively easy to master, if a standardised recording and scoring system is present. As an additional advantage, they can be recorded on fragmentary remains, making them very suitable for bone material from both archaeological and forensic contexts. NMTs are not only useful for archaeologists or physical anthropologists. Although DNA studies keep progressing and are the primary method when genetic material can be retrieved, NMTs can prove their value in forensic sciences (pers. comm. M. Groen, 2012). Especially in older cases, when retrieval of DNA is impossible due to severe degradation or contamination of the skeletal material or soft tissues, or when antemortem dental imagery is not available, anatomical skeletal variants revealed in X-rays or other medical photographic imagery may provide the comparative evidence necessary for a positive identification (Singh 2010). Skeletal NMTs that are prevalent in different populations can be considered when establishing a biological profile, especially when dealing with severely commingled remains recovered from sites with multiple burials (e.g. mass graves from genocide or disasters) (Singh 2010).

In this thesis I will employ a selection of 26 skeletal NMTs, divided into three categories: mechanical (environmental), genetic, and ambiguous. At this moment, it is not possible to determine the exact heritability of every NMT. Therefore, it cannot be excluded that a mechanical NMT has a significant genetic factor, or that the genetic predisposition to develop a NMT is triggered by certain mechanical or environmental factors.

Dental NMTs are excluded from this study, since they are under

much higher genetic control than skeletal NMTs. Also, the specific focus of this thesis is skeletal NMTs, since their aetiology is more heterogeneous. In anthropological studies, this heterogeneity is often disregarded or not properly taken into consideration, although more research on the cause of skeletal NMTs is certainly needed.

1.5. Non-Metric Traits and Genetics

1.5.1. Embryology

The development of genetic variants can be considered as an ontogenic parcours, in combination with genetics that make up the specific details of a particular trait. Most NMTs have a primary genetic basis for their formation, but the extent of the development of a trait may be explained as the outcome of interdependent osseous growth and adaptive processes. This process can be illustrated by the example of branching nerves or vessels, which may result in the formation of multiple canals or foramina: while the branching itself is mainly genetically explained, the formation of the canals or foramina depends mainly on interdependent growing processes (Hauser and DeStefano 1989).

1.5.2. Genetics

All NMTs can be regarded as threshold characters, a term used in the model by Douglas Falconer (1965). This model postulates that there is a *liability* to develop a trait. This liability represents the individual's inherited tendency to develop a trait and the whole combination of circumstances that make the individual more or less likely to do so. Whether the individual shows the trait or not, depends on his or her position relative to the threshold (i.e. the "*breakpoint*"). If the threshold is reached (i.e. above the breakpoint), the trait will manifest. The individual's genes, together with environmental effects, will result in different variations of trait expression (weak or strong) (Falconer 1965). In Fig. 1.1. a bell curve graphic is shown with a threshold line. Left to the threshold line, a NMT will not manifest. On the right side of the threshold line, the

trait will manifest, with varying levels of expression. In this model, the NMT has an incidence of 20% in a population. The stippled portion of the graphic indicates the affected individuals (Falconer 1965) (see Fig. 1.1.).

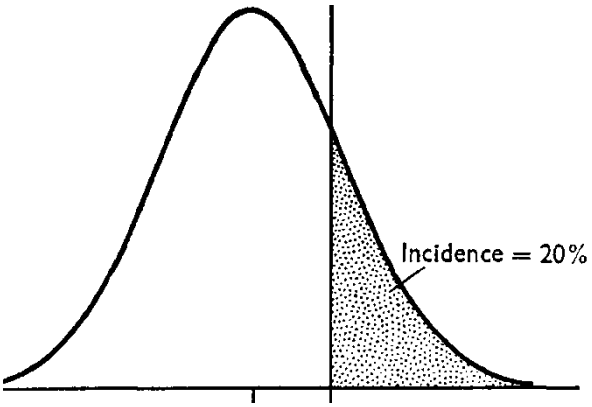


Fig. 1.1. Bell curve model with threshold.
(Adapted from Falconer 1965, 53.)

A few years earlier, British geneticist Hans Grüneberg (1963) had found that certain strains of lab mice consistently yielded individuals with missing third molars. These individuals also had smaller and more variable teeth than strains of mice with a third molar. He concluded that tooth size was the inherited characteristic, rather than the absence of a certain tooth. If the tooth germ is too small, the tooth fails to develop, i.e. when its prospective size falls below the threshold level (Grüneberg 1963 in Hillson 1996). Although it is still uncertain whether these variants in mice are similar to development in humans, it seems reasonable to suppose that the genetic basis is not completely different (Grüneberg 1951 in Berry and Berry 1967).

1.6. Middenbeemster

A selection of NMTs will be studied in the 17th-19th century skeletal assemblage from the village of Middenbeemster, North-Holland (the Netherlands), from the churchyard of the protestant Hendrick de Keyser church, which was in use from 1612 to 1866 AD.

Due to planned construction on the south side of the church, exploratory research was done by Hollandia Archaeologists, in order to

establish if any human burials or other archaeological remains were present in the planned building-zone. In March 2011, Hollandia placed a number of test trenches, in which 35 graves were recognised. The graves contained well-preserved skeletons of both adults and infants. It became clear that graves were present at more than one level. During the exploratory research, besides the bone material, two pottery fragments dated between 1600-1800 AD, and two plain metal coffin handles were recovered.

In the Summer of 2011, from June 14th until August 5th, the churchyard was excavated by students of the Faculty of Archaeology, Leiden University, in collaboration with Hollandia Archaeologists (see Fig. 1.2.). The physical anthropological aspect of the excavation was handled by Leiden University, whereas Hollandia cared for the other archaeological finds, such as pottery, metal, wood and glass. In the end, almost 500 skeletons were excavated. Additional information about Middenbeemster will be provided in chapter 2.

Fig. 1.2. 2011 excavation in Middenbeemster. Source: photograph by author.

1.7. Research Questions

In current osteological research no distinctions are made between the NMT categories. Despite clear causal differences, the mechanical, genetic, and ambiguous categories are generally lumped together. A more profound understanding of mechanical NMTs provides new views into the occupational activities of the past. Studying genetic NMTs can contribute to studies into genetic relatedness within a population or assemblage, especially when the retrieval of DNA is not possible.

The main objective of this thesis is twofold. The first objective is to

provide an assessment of the selected NMTs in the skeletal collection from Middenbeemster. Statistical analyses will be used to determine if there are differences between males and females, or between different age groups. The second objective is to gain more insight in the often blurred distinction between the mechanical (environmental), genetic, and ambiguous NMT categories. All NMTs are multifactorial, but this thesis will attempt to determine which are most highly heritable (and thus useful for biodistance studies) and which are least heritable (and therefore not appropriate for biodistance). The determination of largely mechanical NMTs will tell us more about the mechanical forces on the skeletons of the Middenbeemster individuals, and can thus provide insight in habitual activities.

The main research questions of this thesis are the following:
Are there significant differences in the frequency of mechanical NMTs compared to genetic NMTs, a) within the Middenbeemster sample, and b) among comparative samples of the same ethnicity?
It is expected that there will be more variation in mechanical NMTs than in genetic NMTs between different assemblages, since it is thought that activities vary more between groups than their genes. Therefore, the null hypothesis is that there will be no difference between mechanical and genetic NMTs between different populations. The null hypothesis can be rejected if there are significant differences between NMT frequencies between the samples.

In order to understand factors that cause variation in NMT occurrence, the following subquestions will be analysed:
First, are there differences in NMT frequency between males and females within the Middenbeemster sample? Second, are there differences in NMT frequency between age groups within the Middenbeemster sample? Differences between males and females or between different age groups suggest that NMTs are affected by sex or the ageing process.

The ultimate goal of this thesis is to contribute to the development of a stricter distinction between the mechanical, genetic, and ambiguous NMT categories in order to better implicate NMT data in future osteological research.

CHAPTER 2. HISTORICAL BACKGROUND

2.1. Introduction

In this chapter a brief introduction to the historical background of the Middenbeemster churchyard and the 18th and 19th century Netherlands as a whole will be provided, for a better understanding of the cultural origins of the skeletal material. At first, the Netherlands as a whole will be described, with an emphasis on health and demographic data, in order to understand the influence of different factors on NMTs and their formation. Nationwide epidemics or diseases that occurred frequently in the country can also provide information about the Beemster health situation. Other background information, such as working environment and dietary practices can help understand mechanical wear of the skeleton and possible nutritional deficiencies, respectively, which can both affect the formation of NMTs.

When studying NMTs, it is key to have a basic understanding of skeletal diseases, since pathological lesions can inhibit the observation and visibility of a NMT. For instance, a severe mastoiditis, an infectious disease of the inner ear, can canker the mastoids and the area of the external auditory meatus, which can inhibit the observation of an auditory exostosis or mastoid foramen.

A comprehensive description of the Middenbeemster site will conclude this chapter, including a brief review of relevant data from the Middenbeemster archives.

2.2. The Netherlands

2.2.1. Health and Cause of Death

It is difficult to gauge exactly what the health conditions were in the 18th and 19th century Netherlands. In most of the larger cities records were kept about causes of death, epidemics, or frequently encountered diseases.

In smaller communities, especially rural ones, data was often only basally recorded. From preserved historical data it is known that fevers were practically endemic, especially in the coastal provinces and river areas, due to the bad quality of the water and the presence of possible malaria mosquitoes (Wintle 2000). Epidemics of influenza, measles, and smallpox occurred on a highly regular basis. Chronic illnesses of the digestive and respiratory system were widespread (Wintle 2000). Probably, almost every individual in every social layer of the population was affected more or less by one of these illnesses. Despite peaks in cause of death during epidemics, the steady killers were evermore the digestive and respiratory system disorders (Wintle 2000). In Amsterdam, during the period of 1774-1883 AD, 45% of all deaths were caused by digestive organs diseases and 25% by respiratory system diseases (Wintle 2000). In the province of North-Holland, where Middenbeemster is located, death rates in the early 19th century were amongst the highest of the Netherlands, with a death rate of 31.6 per 1000 individuals in 1816 and 26.8 per 1000 individuals in 1870 (Wintle 2000).

In the entire country, drinking water was a source of sometimes fatal illness, caused by flourishing bacteria in ditch-water and the dumping of refuse, industrial waste, and human and animal feces in water that was also used to bathe in, cook with, and drink from (Wintle 2000). In almost all provinces, a chronic shortage of food was common, although the diet was remarkably diverse. Bread and potatoes made up the majority of the food, with occasionally some fruits and vegetables. Sometimes fish was eaten, contrary to the rarely eaten, expensive meat (Wintle 2000). It is possible that meat made up a larger part of the diet in the cattle-farming Middenbeemster community than in the average Dutch population.

Most people drank milk or the cheaper buttermilk, tea, beer or a weak brew of coffee or licorice. On festive days, *jenever* (Dutch gin) was pulled out (Wintle 2000). Despite the relatively diverse food options, it is important to note that most people, except those from the highest classes, suffered a light to chronic malnutrition (Wintle 2000).

It seems manifest that (periods of) disease and/or dietary insufficiency during childhood or adolescence could impact physical growth and the development of NMTs. In a random bred strain of mice, it appeared that maternal diet played a large role in generating certain skeletal NMTs (Leamy and Self 1978). Although research with laboratory animals has demonstrated the effect of diet on NMTs, it is believed that these differences are at much lower levels than those produced by genetic factors (Ossenberg 1970). Literature about the specific influence of diet on the formation of NMTs is scarce. Hitherto, no competitive research about the influence of diet on the formation of NMTs has been performed in human populations.

Manzi *et al.* (2000) have suggested that the variation between hypostotic traits (lack of ossification) and hyperostotic traits (over-ossification) is related to physical, mechanical stress, suffered by bony structures during early stages of growth and development. They hypothesise that hypostotic traits are markers for the occurrence of "ontogenic stress" (physiological stress during an organism's origin and development), since hypostotis represents insufficient or arrested development (Manzi *et al.* 2000). It seems plausible to suggest that hypostotic traits are perhaps more prone to develop in periods of malnutrition, disease, or other physical stress, when all strength is employed to keep the body in balance and recover from the stressful period, resulting in incomplete ossifications (Manzi *et al.* 2000).

2.2.2. Employment

Knowing how the members of the Middenbeemster population were employed, can provide relevant information for the research into mechanical NMTs. A number of NMTs is largely formed by external mechanical stress and/or repetitive habitual actions, such as the tibial and talar squatting facets. Certain NMTs can even be directly associated with a specific occupation. An interesting example is the high frequency of os acromiale within the skeletons of the seamen of the drowned 16th century

war ship, the Mary Rose. This is probably associated with the regular use of a heavy bow. The specific technique employed in order to shoot the bow may account for the dominance of os acromiale on the left side (Fury 2012). Despite the ambiguous cause of the os acromiale, it seems evident that in this case the high frequency was caused by the repetitive, habitual handling of the bow from a young age. Another example is the higher frequency of talar and tibial squatting facets in many African and Asian peoples, who perform many daily activities in a squatting position (Barnett 1954).

Because the Middenbeemster churchyard was only recently excavated, the archival research is still ongoing. It should be noted that in this preliminary stage, archival data cannot yet be directly linked to the excavated individuals. However, the archival data does present an opportunity to take a look into the different professions in Middenbeemster. In the municipal archives of the Beemster, death registers were found that contained an individual's name, age at death, date of death, and profession, as well as the name, profession, and relation to the deceased of whoever declared the individual dead. In the registers from 1830 to 1835 a wide range of professions were listed, including: workers, tailors, handmaidens, housewives, sailors, water millers, cargo drivers, garden aids, saddle makers, village policemen, cobblers, merchants, servant girls, mill bosses, innkeepers, gardeners, bakers, carpenters, preachers, artists, tailor's servants, housekeepers, heralds and bartenders (Middenbeemster death registers, 1830-1835) (see Fig. 2.1.). It should be noted that the majority of the population was often (seasonally) employed in the agricultural or fishing sector as well, additional to their other occupation(s). Other large sectors were manufacturing and building (see

Fig. 2.1. Three servant maids, ca. 1885, UK. Source: www.8hourday.org.au

Table 2.1.) (Wintle 2000). After their day jobs most people worked their own small garden to supplement their diet with some home grown fruits and vegetables. Most households attempted to produce a small surplus of certain goods to sell at local markets, in order to replete the household finances (Falger *et al.* 2012).

The large amount of professions in the Beemster area helps to understand why it is so hard to distinguish certain individuals or groups that exhibit more mechanical NMTs. With the practice of such a wide range of professions, the mechanical NMTs are bound to show a corresponding amount of diversity.

Table 2.1. Occupations during the 19th century, in percentages.
(Adapted from Wintle 2000, 78.)

Sector	1807	1849	1859	1889
Agriculture/fishing	42,8%	43,8%	37,5%	32,9%
Extraction	0,2%	0,2%	0,2%	0,9%
Manufacturing	19,1%	19%	20,7%	22,5%
Building	6,6%	4,8%	5,4%	6,9%
Trade/finance	7,2%	6,4%	6,7%	9,3%
Transport	4,5%	4,5%	5,5%	6,8%
Other services	18,9%	17,9%	21,5%	19,3%
Other/remaining	0,7%	2,8%	2,6%	1,0%

2.2.3. Child Labour

It was common practice in the 18th and 19th century to employ the entire family, children included. Particularly in the 19th century, after the onset of the Industrial Revolution, conditions were especially grim in large factories. Workers and child labourers alike were forced to work twelve to twenty hours a day, in dangerous conditions (Verniers-Van der Loeff *et al.* 1887). Accidents at work were no rarity. In a British government survey from 1841, it was concluded that large numbers of young children and youth were employed nation-wide, in virtually all trades and industries (Wintle 2000). Similar situations were reported in other Western-European

countries, such as the Netherlands, Germany and France (Wintle 2007).

In the Netherlands, on September 19th, 1874, Mr. Samuel van Houten, a social-liberal member of parliament, took the initiative to formulate his "Children's Law" against excessive use of labour and neglect of children. This law forbade labour in factories and sweatshops by children under the age of twelve and limited working hours for adults to a maximum of eleven hours a day (Heywood 1988). Notwithstanding the 1874 Law, children were still widely employed for decades afterwards (Verniers van der Loeff *et al.* 1887).

No large factories were present in Middenbeemster or its direct surrounding, so the Middenbeemster children were probably never employed in a factory environment. Since Middenbeemster was an agricultural community, every extra pair of hands was welcome. Children were deployed in all areas of life to aid their parents, for instance on the field, for grubbing, weeding, and sowing, especially during the busy harvest months. Older children were also used as babysitter and often contributed significantly to the nurture and education of their younger siblings (Heywood 1988).

It has been shown in both animals and humans that periods of extreme physiological stress can impact physical growth and the formation of NMTs. It has been suggested that mechanical stress suffered during growth and development may have an impact on the formation of especially hypostotic traits, since these represent arrested development during infancy and adolescence. (See also chapter 2.2.1. Health and Cause of Death.)

2.2.4. Social Stratification

Dutch society was deeply stratified into the 20th century (Wintle 2000). In the 18th and 19th century the top of the status pyramid consisted of a small percentage of traditional patricians, with locally based power. Below them was the new moneyed class, with wealthy, well-educated people, who challenged the established position of the patricians. A large percentage of

the Dutch society was made up of the lower middle class. The wealthier among these individuals had some possessions, like houses or land. At the bottom of this stratified society were the "masses": the impecunious, who were at the time politically insignificant. This stratification applies to both rural and urban communities (Wintle 2000).

It is to be expected that in the high standing classes fewer mechanical NMTs will be present, since members of these classes did not perform heavy labour or other strenuous habitual activities. In contrast, a higher number of mechanically influenced NMTs is anticipated in the lower classes, who did perform day-to-day physiologically demanding work. Note that this division in presence of mechanical NMTs is not specifically related to someone's wealth, but to a person's occupation. Genetic NMTs are expected to occur at an equal rate in all social classes, since it is anticipated that genes vary less in people from the same population.

2.3. Middenbeemster

In the following section a description of the Middenbeemster site will be provided, with attention to its historical formation and background, followed by a brief selection of relevant archival data regarding burials.

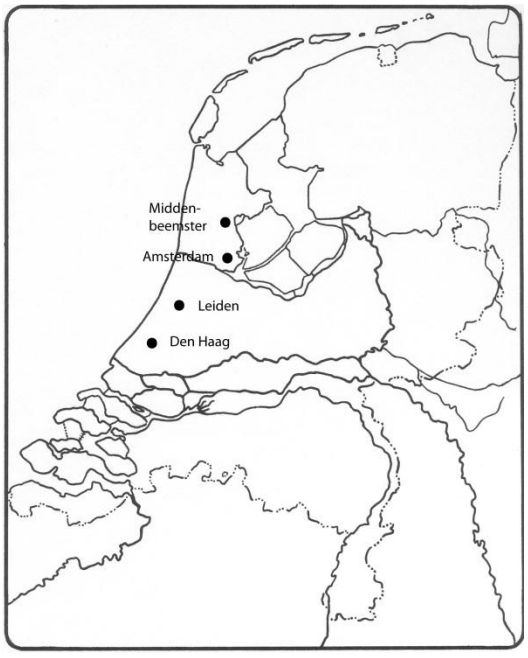


Fig. 2.2. Map of the Netherlands, with northernmost Middenbeemster. Source: www.digischool.nl

Middenbeemster is a small village located in the Beemster polder of North-Holland (see Fig. 2.2.). Heretofore, the entire area was a lake, but in the early 17th century, large areas of North-Holland were drained for land reclamation (Falger *et al.* 2012). The newly retrieved land was divided in a strict cadastre, with the village of Middenbeemster (initially

Middel Beemster) in the middle, located at the intersection of the two main roads. The fertile soil that was unlocked after the land reclamation was originally used for agriculture. Crops such as grain, rapeseed, and linseed were cultivated (Falger *et al.* 2012). In the course of time, agriculture was replaced by animal husbandry, due to groundwater levels and the quality of the soil, which proved less suitable for extensive agriculture. The Beemster exported wool, butter, cheese, and bulls (Falger *et al.* 2012). Centuries of agriculture and the export of demanded goods has made the Beemster a successful agricultural area up to this day, characterised by its large estates. In recent times, horticulture has expanded considerably. Since 1999, the historic polder landscape with its still largely intact grid pattern has been listed as World Heritage by UNESCO.

2.3.1. Geological Buildup of the Site

The soil of the Middenbeemster site consists of several sedimentary layers. Before the land reclamation, the Beemster was a chain of peat bogs, protected from the sea by ringdikes and the Kennemerland dunes (Falger *et al.* 2012). The Middenbeemster soil consists of a natural subsurface of greasy, blue clays, that formed the lake bottom. These clays are covered with a layer of white, finely grained sand, interspersed with shells, deposited by creeks and small currents that penetrated from the open coast (pers. comm. S. Hakvoort, 2011). After the closing of the coast line and the formation of high sand dunes by aeolian processes, fewer salt water inundations occurred. This resulted in the formation of a brown layer of humous peat. The peat is covered by modern, human-made embankments, consisting of clay, sand, and peaty sediments, retrieved from the deeper layers (pers. comm. S. Hakvoort, 2011).

2.3.2. Middenbeemster Church

After the draining of the Beemster in the 17th century, it was initially decided that five churches would be built in the new polder (Falger *et al.*

2012). Eventually, only the Middenbeemster church was constructed. In 1615 AD the design of the church was entrusted to the Amsterdam architect Hendrik de Keyser. In 1618 AD the construction commenced. Three years later, in 1621, the tower was completed. In 1623 AD, the church was ceremoniously consecrated. In following years two annexes were built, as well as a heightening of the tower (Falger *et al.* 2012).

From 1638 to 1829 AD, people were buried both inside the church as well as in the outside churchyard. Both Catholics and Protestants were buried in the Middenbeemster churchyard. In 1829 AD the Beemster civil administration acquired management over the Middenbeemster churchyard and made it into the communal churchyard (Falger *et al.* 2012). In the same year burials inside churches were banned, so after this date people were only buried outside. Bone pits and disturbed burials indicate that removal of graves took place, although it is unlikely that these were total clearances. The removal of burials probably took place during the course of years (pers. comm. M. Hoogland, 2013). The churchyard was in use until 1866 AD. After this date, burials on the property of the church were no longer allowed and prohibited by law. After the commencement of this law, some corpses from the most recent burials were removed from the churchyard to the new communal graveyard (Falger *et al*. 2012). Archival records indicate that the majority of the burials date to the 19th century.

2.3.3. Archival Data

In 1617 the Middenbeemster churchyard was mentioned for the first time in the historical register. It was noted that carpenter Limborg Jansz. was appointed as the municipal undertaker, together with exact rules for the depth of a burial pit and the costs for a burial (see Fig. 2.3.) (Falger *et al.* 2012, 27).

1617, 14 februari: "Tot graffmackerschap aen de Middel Beemster wort gecommitteert Limborg Jansz. timmerman aldaer. Ende met eenen verstaen dat men geen luyden binnen maer alle buyten de kercke sal begraven Ende dat de graven op de diepte van vier voeten gemaeckt sullen worden daervan de graffmacker sal genieten van ijdel parssoon volgende d'ordre van Amsterdam. Daer en boven noch voor 't recht van de begravenis van een kint beneden die vier jaeren ses stuyvers ende beneden de vijftien jaeren twaalff stuyvers ende voor personen daer en boven oudt wesende vierentwintich stuyvers ten profijte van de kercke aen handen van mr. Marten van den Eijnde betaelt sullen werden die pertinente notie van sijn ontfanck ende van de selve begravenisse sal houden." (From Falger *et al*. 2012, 27.)

Free translation:

1617, Februari 14th: As undertaker of the Middel Beemster is appointed Limborg Jansz., carpenter. No people will be buried inside the church, only outside. The graves have to be made at a depth of four feet by the undertaker, according to the Amsterdam rules. A child younger than four years costs 4 *stuyvers* [pennies], under fifteen years twelve *stuyvers,* and for persons older than that twenty-four *stuyvers*, for the benefit of the church, paid to Mr. Marten van den Eijnde, who shall make a note of what he has received, and of the burials themselves. (Translation by author JKV.)

Fig. 2.3. Excerpt from historic Beemster archives on burials.

CHAPTER 3. MATERIALS AND METHODS

3.1. Introduction

In this study NMTs are examined in a sample of skeletons from the 17th to 19th century Middenbeemster churchyard, in order to assess the presence and frequency of NMTs with purportedly different causes, namely genetic, mechanical, and ambiguous. Furthermore, the influence of repetitive physical stress on the formation of mechanical NMTs will be examined. This is achieved through intrapopulational research, by determining the presence of NMTs within different age and sex categories, after which a demographic spread can be made. Following, an interpopulational comparison will be made between the Middenbeemster sample and NMTs within other Caucasian assemblages. The comparative assemblages will serve as the standard to which the results of the Middenbeemster sample will be compared. Since NMTs occur at a different frequency in different assemblages, especially in other ethnicities, the reliable way to compare NMTs within the same ethnic group is using percentage data.

The skeletal collection of Middenbeemster provides an exceptional opportunity to study morphological, non-metric variation in a sample with extraordinary preservation. Not that often, archaeological skeletal material is uncovered from individuals, whose archival data is still present, with information about sex, age, social status, familial genealogies, and professional occupations. Archival data permits the determination of genetic affinity, which will facilitate assessment of the heritability of different NMTs. Insight about the professions of these individuals will help us understand the impact of occupation-related physical stress on the formation of mechanical NMTs.

3.2. Ethics

A common, yet delicate issue in archaeology is the ethical treatment of human remains that are encountered during excavations. Only in 1989, at the World Archaeology Congress in South-Dakota, it was decided that "respect for the mortal remains of the dead shall be accorded to all, irrespective of origin, race, religion, nationality, custom, and tradition" (first rule of the Vermillion Accord on Human Remains, adopted in 1989 at the South-Dakota World Archaeology Congress). In the Netherlands, when old cemeteries are cleared or when human skeletons are encountered, the rules of the WLB (Wet op Lijkbezorging, *Law on Funerals*) are observed, as is noted in the Behavioural Code for Professional Archaeologists. This means that all human remains are treated with respect during excavation and research. In many cases the human remains are reburied or cremated after research (Gedragscode voor Beroepsarcheologen van de NVvA. Ethische Gedragsregels en Principes voor Nederlandse Archeologen 2001; Wet op Lijkbezorging 2010). Cultures from all over the world treat their deceased in different ways, and as archaeologists, we should respect that.

In a number of years, the Middenbeemster research will be completed. It is possible that the skeletons will be repatriated to the Middenbeemster community for reburial, or that they will form the basis for an extensive teaching collection in the Laboratory for Osteoarchaeology. Hitherto, no final decisions have been made regarding this matter.

3.3. Materials

The human skeletal material comes from the 2011 excavation of the Middenbeemster churchyard, performed by Leiden University and Hollandia Archaeologists.

The Middenbeemster churchyard was in use from 1617 AD to 1866 AD. More than 500 skeletons were unearthed from an area measuring circa 250 m^2. Historical research has revealed 676 registrations in the

Middenbeemster archives, recorded from 1829 to 1866 AD. Sex was listed for 445 individuals, both adults and subadults: 225 were female (50.6%) and 220 were male (49.4%), therefore an even sex distribution. Age was recorded as well for the registered 676 individuals.

For this thesis, 93 randomly selected adult skeletons were analysed. The total of 93 skeletons consisted of 39 males, 38 females, 6 probable males, and 10 probable females. Thus, there is an almost equal number of males (n=39, with probable male included n=45) and females (n=38, with probable female included n=48), adequate for the desired proportionate sample. During sampling, 1 indeterminate individual was analysed. After the macroscopical analysis of the skeletal sample had been completed and had proved amply comprehensive, it was decided to remove the sole indeterminate from the subsequent analysis. Both sexes were practically equally represented in each age category, except for the Old Adult category with nine males versus four females (and one probable male and one probable female). In the sample, 17 Early Young Adults were present, 26 Late Young Adults, 30 Middle Adults and 15 Old Adults. Five individuals were categorized as a Middle/Old Adult, due to ambiguity in the results after age determination (see Table 3.1.).

Table 3.1. Number and percentage of individuals per age category.

Age Group (years)	**M**	**%**	**F**	**%**	**PM**	**%**	**PF**	**%**	**Total**	**%**
EYA (18-25)	7	**17.1**	6	**16.7**	2	**33.3**	2	**20.0**	17	**18.3**
LYA (26-35)	12	**29.3**	13	**36.1**	1	**16.7**	0	**0**	26	**28.0**
MA (36-49)	11	**26.8**	11	**30.6**	2	**33.3**	6	**60.0**	30	**32.3**
OA (50+)	9	**22.0**	4	**11.1**	1	**16.7**	1	**10.0**	15	**16.1**
MA/OA	2	**4.9**	2	**5.6**	0	**0**	1	**10.0**	5	**5.4**
TOTAL	41	**100**	36	**100**	6	**100**	10	**100**	93	**100**

Pathological conditions affected all age categories and both sexes approximately equally. In the Early Young Adult category both males and females exhibited fewer numbers of pathological lesions or abnormalities. It should be noted that certain pathologies can affect NMTs. Specimens with severe pathological lesions on sites where one would expect a NMT were excluded, since sites of trauma –both healed and unhealed- can conceal NMTs. Additionally, a pathological condition may have a similar appearance to a NMT, or vice versa. If an entire skeleton was to such an extent affected by the aging process or pathological conditions, that the visibility or expression of NMTs was seriously impeded, it was excluded.

After the basic determination of age, sex, and pathology (see chapter 3.4 Methodology), the skeletons were visually examined for cranial and post-cranial NMTs. The presence or absence of NMTs was subsequently scored, following a predetermined list with descriptive details, as elaborated upon in Appendix III. Other observations, such as preservation or completeness, were noted if relevant.

3.4. Methodology

After the outline of the theoretical framework in which this research is placed, the next step is the osteological analysis of the morphology of the skeletal remains on a macroscopical level. The primary focus of the skeletal analysis is to register all observable cranial and post-cranial NMTs on a recording form drafted by the author (see Appendix III). Appendix I provides the definitions for the selected NMTs. It was attempted to select post-cranial NMTs in such a way that at least one NMT was present on most of the infracranial skeletal elements. Since cranial NMTs are high in number and have been extensively studied, relatively more cranial NMTs will be examined. The basic assessments of age, sex, and pathological conditions will be noted. If known, the social status of the individual will be noted, in order to gain insight in the prevalence of certain NMTs within a part of the population, e.g. a higher prevalence of a specific mechanical NMT within a specific professional group. For the purpose of this research, Early Young Adults (18-25 yr.), Late Young Adults (26-35), and

Middle Adults (36-49 yr.) are preferred. Since it is expected that this will have negative consequences for the sample size, Old Adults (50+ yr.) will be included as well, on the condition that age-related hyper- or hypostoses do not obscure the NMTs.

Caution should be taken not to mistake the large muscle attachments in this overall robust population for a NMT, especially in the bulkier males. Finally, it is important to distinguish between damage as the result of taphonomic processes and a NMT.

3.4.1. Sex

The sex of the analysed skeletons was determined using the methods from the Workshop of European Anthropologists (WEA 1980). Within these methods, the pelvic bones are the most important for sex determination, followed by cranial traits, and long bone morphology and measurements. The sex determinations have been complemented with Phenice traits of the pubic bone (Phenice 1969). Additional information regarding sex differences in adults is derived from Buikstra and Ubelaker's "*Standards for Data Collection from Human Skeletal Remains*" (Buikstra and Ubelaker (eds.) 1994).

3.4.2. Age

The skeletons used in this sample have been assigned an age using different methods. The Suchey-Brooks method has been used to estimate age based on the development of the pubic symphysis (Brooks and Suchey 1990). The method by Isçan *et al.* (1984) uses metamorphosis at the sternal end of the right and/or left 3^{th}, 4^{th}, 5^{th}, or 6^{th} rib to assign an age (Isçan *et al.* 1984). Ectocranial suture closure, assessing both vault sites and lateral-anterior sutures, using the revised method by Meindl and Lovejoy (1985), has been employed to estimate a mean age and age range (Meindl and Lovejoy 1985). Much weight was put on the revised method by Buckberry and Chamberlain (2002), which uses the chronological metamorphosis of the iliac auricular surface. Scoring the different locations of the auricular

surface results in a composite score, which leads to a mean age and age range, often proving a valuable age indication (Buckberry and Chamberlain 2002)? Adjuvant for the latter method has been the 1985 article with clear, explanatory illustrations of the iliac auricular surface by Lovejoy *et al*. (Lovejoy *et al.* 1985). The method by Maat (2001) to determine age at death from molar attrition, has shown its use, although in many cases it was used mainly as a gross indication, due to regular antemortem and postmortem tooth loss and major caries at a young age in this population (Maat 2001). Additional information regarding age changes in adults was derived from Buikstra and Ubelaker (eds.) (1994).

3.4.3. Pathology

Frequently noticed pathological lesions or abnormalities of the skeleton and dentition were recorded. Pathologies range from congenital conditions (bathrocephaly, spina bifida) to infectious diseases (mastoiditis, sinusitis, tuberculosis), fractures, and age-related pathological changes (osteoarthritis, eburnation, vertebral fusion). All pathologies have been described and photographed.

3.4.4. Skeletal Non-Metric Traits

The cranial NMTs that have been analysed in this sample are derived from Hauser and DeStefano's "*Epigenetic Variants of the Human Skull*" (1989). The post-cranial traits come from Buikstra and Ubelaker (eds.) (1994) and Finnegan (1978). In Appendix III each trait is listed, with its cause indicated. The scoring list used in this study was derived from scoring systems used by Hauser and DeStefano (1989), Buikstra and Ubelaker (1994), and Finnegan (1978). For some traits, the scoring system was adopted unaltered. Other traits were allotted new scores, in most cases an amalgam of different methods and scoring systems, sometimes simplified, sometimes made more elaborate, but in all cases adapted to fit the specific needs of this thesis. In Appendix III the scoring system for each trait is shown. An abbreviated list of traits is shown in Table 3.2.

3.5. Non-Metric Sampling and Analysis

The trait list was developed after careful consideration of a wide range of skeletal non-metric variation. At the outset, each trait is trichotomously scored as Present (P), Absent (A), or Unobservable (U). Traits were scored as Unobservable when a skeletal element was missing or the location of a NMT was too heavily affected by taphonomic or pathological changes. After the initial scoring, the majority of the Present traits were provided with a more detailed description about the trait, for instance about its specific size, location, or number. In total 26 NMTs were examined: 11 cranial and 15 post-cranial.

For the skull the following traits were observed: metopic suture, supraorbital foramen, auditory exostosis, mastoid foramen, bregmatic ossicle, parietal foramen, highest nuchal line, double condylar facet, palatine torus, mylohyoid bridge, and mental spine. In the post-cranial skeleton the following traits were observed (in parentheses the bone upon which the trait occurred): double atlas facet (atlas), sacralisation (sacrum), sternal foramen (sternum), os acromiale (scapula), supracondylar process and septal aperture (humerus), trochlear spur (ulna), third trochanter and Poirier's facet (femur), supernumerary rib (rib), acetabular crease (pelvis), vastus notch (patella), tibial squatting facets (tibia), talar squatting facets (talus), and double calcaneal facet (calcaneus) (see Table 3.2.).

Table 3.2. List of examined skeletal non-metric traits, with scoring.

Cranial NMTs	***Additional Descriptions, if Present***
Metopic Suture	Trace; partial (halfway); full suture
Supraorbital Foramen	-
Auditory Exostosis	Spicule; canal occluded <⅓; canal occluded >⅓
Mastoid Foramen	Temporal; occipital; occipitomastoid suture
Bregmatic Ossicle	-
Parietal Foramen	Left; right; bilateral
Highest Nuchal Line	Trace; medium; strong; extreme
Double Condylar Facet	Joined; separated
Palatine Torus	Trace; partial; complete
Mylohyoid Bridge	Trace; partial; complete bridge
Mental Spine	Small <2mm; large >2mm
Post-Cranial NMTs	***Additional Description, if Present***
Double Atlas Facet	-
Sacralisation	L5/S1; L6/S1 and left side; right side
Sternal Foramen	Pinhole; true perforation
Os Acromiale	-
Supracondylar Process	-
Septal Aperture	Pinhole; true perforation
Trochlear Spur	Partial; complete division
Third Trochanter	-
Poirier's Facet	-
Supernumerary Rib	Thoracic; cervical and left; right
Acetabular Crease	-
Vastus Notch	-
Tibial Squatting Facet	Small; medium; large
Talar Squatting Facet	-
Double Calcaneal Facet	-

3.6. Statistical Analyses

After all data was collected, it was entered in an Excel datasheet. For the analysis of the data in this research, the software system SPSS (Statistical Package for the Social Sciences, version 19) was employed. The statistical methods applied to the Middenbeemster data are the one-way ANOVA, Tukey's HSD test, and the t-test. A one-way ANOVA (ANalysis Of VAriance) is a widely-used statistical model that is applied to test hypotheses regarding the means of a certain dataset, when several populations are concerned. It analyses the variance of values of a dependent variable, through a comparison against another set of values, the independent variables (Griffith 2010). In conjunction with the ANOVA, a Tukey's HSD test (Honestly Significant Difference) can be used. A Tukey's HSD test analyses if the means from different datasets have a statistically significant difference (Griffith 2010). A t-test is another common statistical test that is used when one wants to determine if two datasets differ significantly from each other (Griffith 2010).

For traits that were scored for both the right and left side, the highest score was used, since this value shows the maximum expression of the genetic potential of the specific trait.

3.6.1. Statistical Notes

The bregmatic ossicle, supracondylar process, and acetabular crease were included during the analysis of the NMTs, but since no individual within the sample exhibited these traits, they were eliminated from the statistics. The scoring of the mastoid foramen, mental spine, and sternal foramen has been altered during statistical entry. For some of these traits, the additional scoring system proved more complex than necessary. Certain additional scores were so rare, that it seemed redundant to place them into a separate category. In some cases, it proved more useful to abandon the additional scoring system and to replace it with the basic scoring system of Present, Absent, or Unobservable. The following NMTs were modified for statistical entry:

- Auditory exostosis. The additional scoring system of: spicule; canal occluded <1/3; canal occluded >1/3, was replaced by the basic scoring system of Present/Absent/Unobservable.
- Mastoid foramen. The additional scoring system of occipital; temporal; occipitomastoid suture, made the statistical entry unnecessarily complicated, since the majority of the individuals exhibited foramina on more than one location. Therefore, it was replaced by the basic scoring system of Present/Absent/ Unobservable.
- Mental spine. Since only one individual exhibited a mental spine larger than 2 mms, the small (<2 mms) and large (>2 mms) category were merged, and solely indicated as Present.
- Sternal foramen. Because of the few sternal foramina within this sample, the pinhole and true perforation categories were merged, and solely indicated as Present.
- Septal aperture. Because of the few septal apertures within this sample, the pinhole and true perforation categories were merged, and solely indicated as Present.

3.6.2. Interpopulational Analysis

Part of testing the hypothesis of this thesis involves a population-based comparison of NMT frequency and variation. All comparative assemblages are of European ancestry, deriving mostly from Western Europe, although in order to increase the number of NMTs with comparative data, individuals of European descent from North America were also considered. Comparative assemblages range in time from Prehistoric to Medieval to modern. The following paragraph provides a brief description of the comparative samples.

Corruccini (1974) looked at 72 cranial NMTs in 321 crania (77 male; 62 female) from the Terry Collection. The remaining 182 crania were either indeterminate or belonged to subadults. Data from these crania was not used as comparison. The Terry collection is composed of 19th and 20th

century AD American individuals from Caucasian and African-American ancestry. Only data from Caucasian individuals was used for this study. Eight traits overlapped with those used in the Middenbeemster sample. In the same year, Caroline Berry (1974) examined a total of 1084 crania, derived from Norway, Iceland, Greenland, and the United Kingdom (some geographical areas were grouped). Seven NMTs overlapped with those used in the Middenbeemster research (Berry 1974). Perizonius (1979) studied 254 Amsterdam crania, of known age and sex (168 males and 86 females of 21 years and older). He used dissection material of Amsterdam inhabitants who died between 1883 and 1909 AD, stored at the Laboratory of Anatomy and Embryology of the Municipal University of Amsterdam. He looked at 249 NMTs of which nine overlapped with those used in the Middenbeemster sample (Perizonius 1979). Recently, Hallgrímmson *et al.* (2005) looked into the skeletal material of 891 Northern-European, Early to Late Medieval individuals (Hallgrímmson *et al.* 2005). Six of the NMTs could be compared to the Middenbeemster research. In 2007, Waldron (2007) concluded the osteological research of the site of St. Peter's church in Barton-upon-Humber, a site dated from the 10th to the 19th century AD. Two cranial and five postcranial NMTs overlapped with those used for the Middenbeemster sample (Waldron 2007). Finnegan (1978) looked at 96 Caucasian skeletons from the Terry Collection, consisting of 50 males and 46 females, with an almost even age spread. He studied thirty post-cranial traits. However, only the chi-square values were presented in this article. The original, numerical data was not included, nor could it be retrieved. Unfortunately, this study had to be excluded, despite being one of the few studies that actually looked at post-cranial NMTs (Finnegan 1978).

Because of the overpresentation of cranial NMTs in the before mentioned studies, four other studies were included, although they only cover single post-cranial NMTs. Barnett (1954) determined the frequency of the talar squatting facet in 100 European tali. Yekeler *et al.* (2006) assessed the frequency of the sternal foramen by scanning the thoracic area in 1000 modern Caucasian individuals (582 males and 418 females

with a mean age of 54). Trotter (1934) determined the frequency of the septal aperture in American Caucasians and African Americans. For this thesis, only the data for the 960 Caucasian individuals (856 males and 104 females) was used. Hunt and Bullen (2007) determined the frequency of the os acromiale in the Terry Collection, using the skeletons of 776 Caucasians (456 males and 310 females of at least 25 years old).

In all, it was possible to find comparative data for 69% of the NMTs analysed in the Middenbeemster sample: 42% of these traits are cranial and 27% of the traits are post-cranial.

CHAPTER 4. RESULTS

4.1. Introduction.

Statistics are a key part in the analysis of osteological data. After the skeletal analysis of an assemblage, statistical analyses are applied to procure numerical evidence for the hypothesis. Statistical analysis provides the techniques to extract additional information from collected data and enables a clear and indubitable understanding of the situation that the data portrays. Statistics are often employed to provide a summary or description of a certain dataset. Statistics rarely provide simple answers, so it all comes down to the interpretation of statistical data.

4.2. Percentage Differences

After the skeletal analysis of the Middenbeemster NMTs some initial percentage overviews were made, that showed a number of differences in certain NMTs. While the majority of NMTs was evenly spread over the male (M+PM) and female (F+PF) category, a few traits showed a notable difference in percentage between males and females. A metopic suture was present in 71.1% of the males and in only 29.2% of the females (see Fig. 4.1.). 31.3% of the females exhibited a mylohyoid bridge, against 16.7% of the males. Although the frequency of the os acromiale was rather low in the entire assemblage, it was more prevalent in females with 9.2%, against only 2.2% in males. A septal aperture was present in 8.4% of the females and in 2.2% of the males (see Fig. 4.2.).

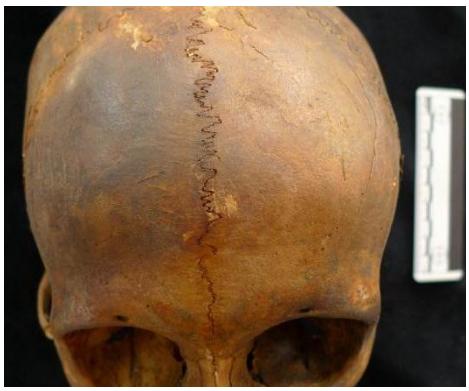


Fig. 4.1. Metopic suture in individual S430V0965.
Source: photograph by author.

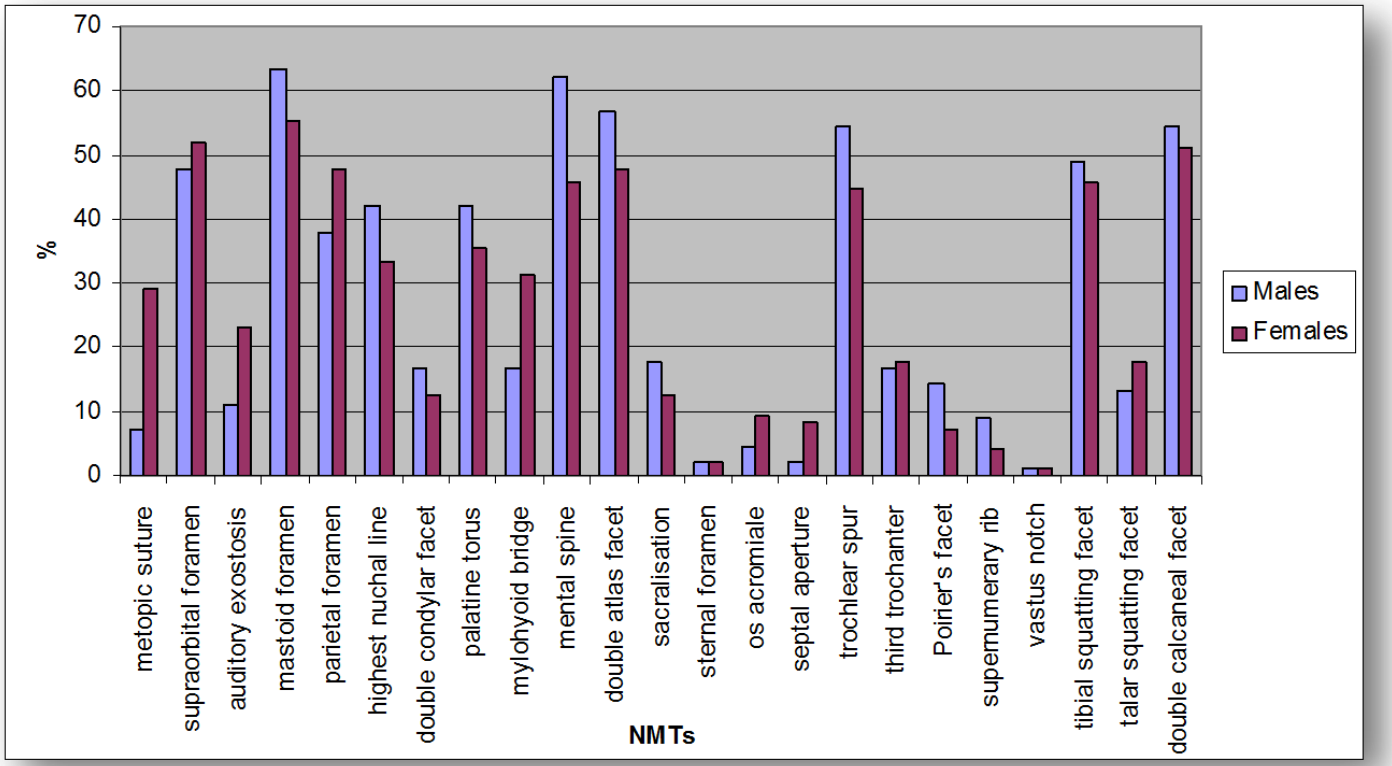


Fig. 4.2. NMTs in males and females, in percentages.

The majority of the NMTs was evenly spread over the four age categories (Early Young Adult, Late Young Adult, Middle Adult, Old Adult), with the exception of a few traits, that showed a notably higher percentage in a certain age category. A metopic suture was present in 73.3% of the Old Adults, compared to 47.1% in the Early Young Adults, 50.0% in the Late Young Adults, and 40.0% in the Middle Adults. A mental spine was present in 88.2% of the Early Young Adults, compared to 46.2% in the Late Young Adults, 40.0% in the Middle Adults, and 53.3% in the Old Adults. An average percentage of left and right of 61.7% of the Middle Adults exhibited a trochlear spur, compared to 35.3% in the Early Young Adults, 48.1% in the Late Young Adults, and 53.4% in the Old Adults (see Fig. 4.3.).

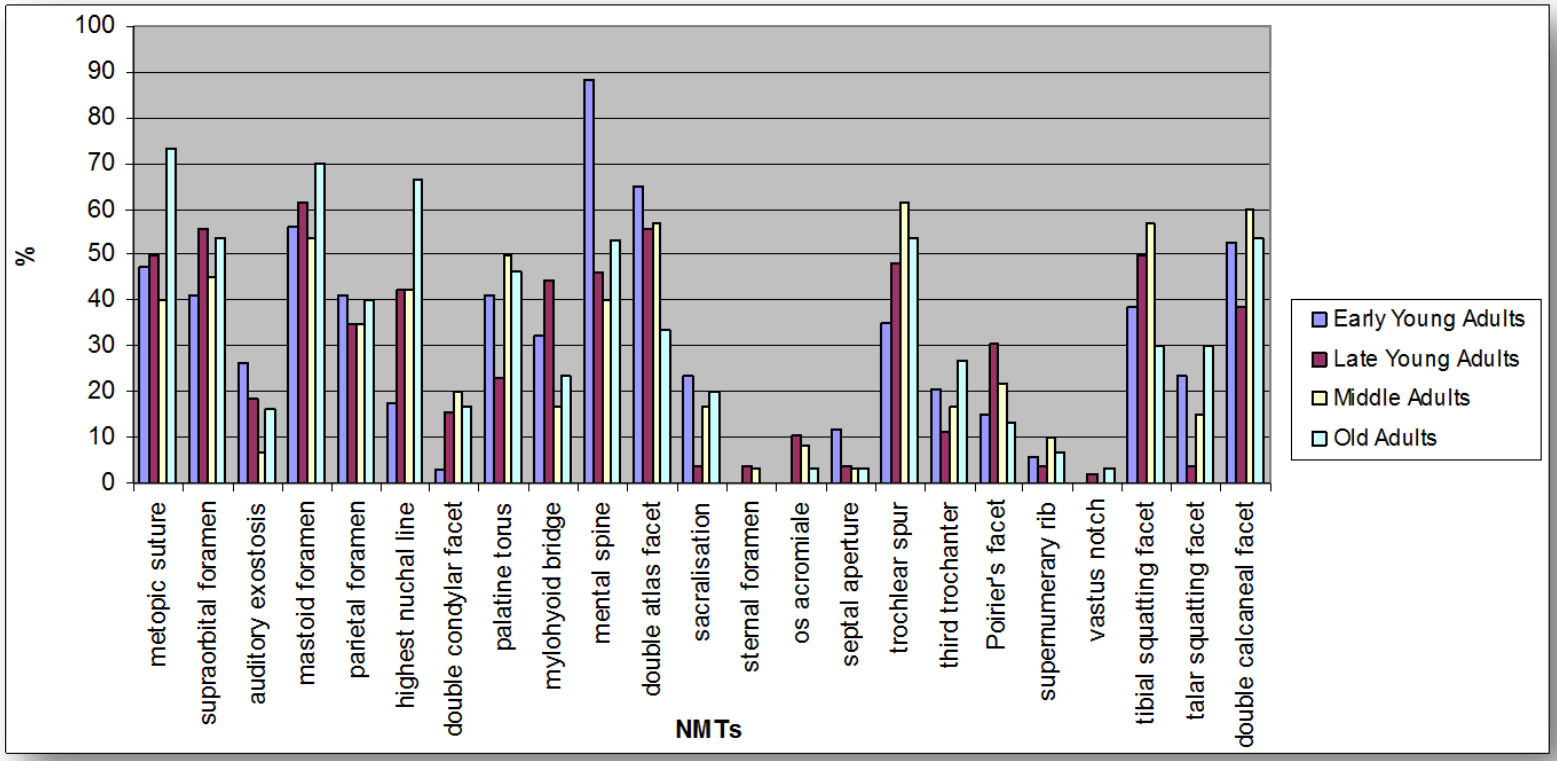


Fig. 4.3. NMTs per age category, in percentages.

The majority of the NMTs was evenly spread over the two pooled age categories, the Young age group (Early Young Adults and Late Young Adults) and Old age Group (Middle Adults, Old Adults and Middle/Old Adults), with the exception of the palatine torus that was present in 46.0% of the Old age Group and in 30.2% of the Young age Group. The mylohyoid bridge had a frequency of (average of left and right) 39.6% in the Young Age Group and 18.0% in the Old Age Group. Of the individuals in the Young Age Group 62.8% exhibited a mental spine, against 46.0% in the Old Age Group (see Fig. 4.4.).

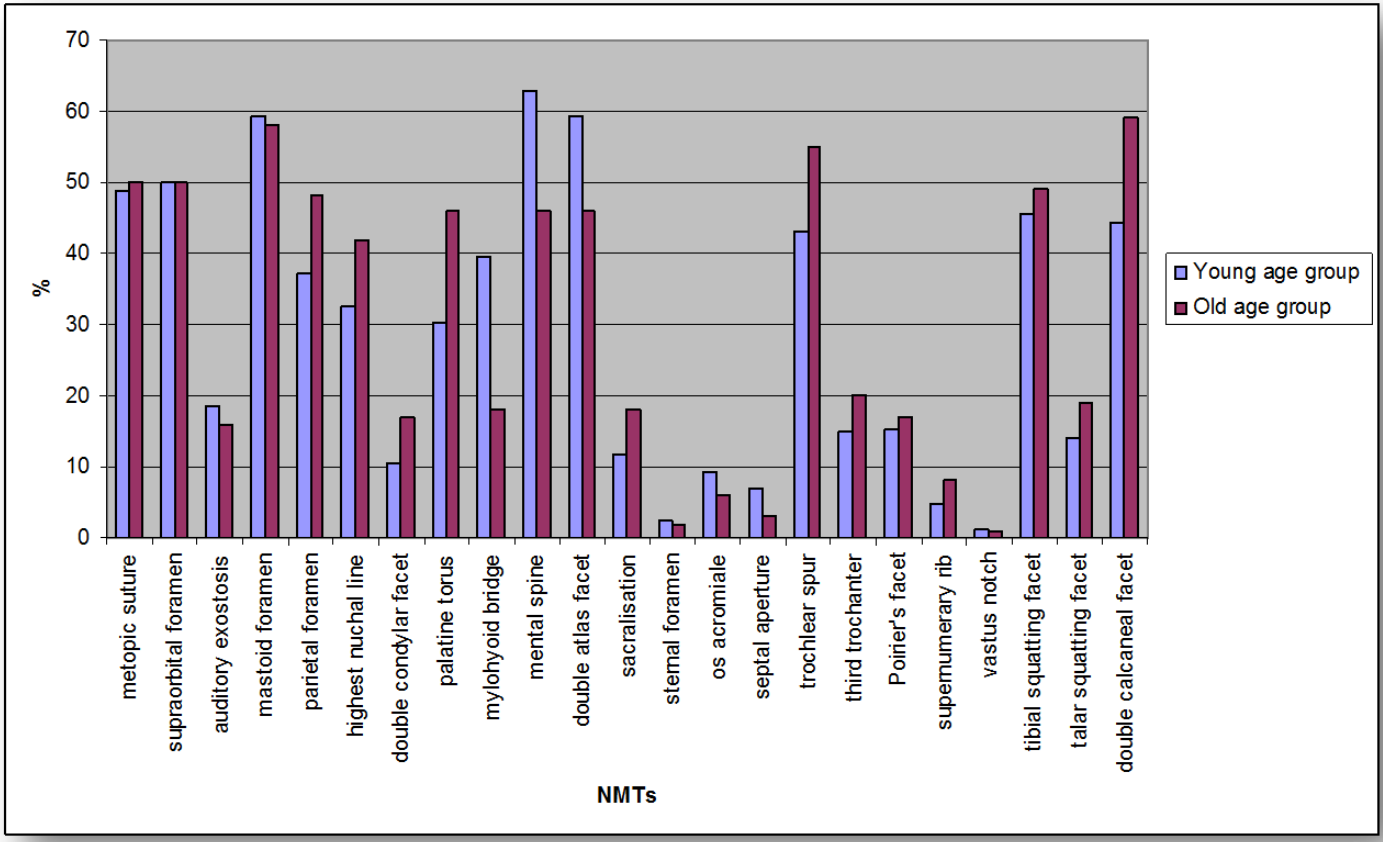


Fig 4.4. NMTs in Young age group and Old age group, in percentages.

4.3. Maximum and Minimum Range

To assess whether a statistically significant difference was present between the genetic, mechanical, and ambiguous NMT groups in the comparative and the Middenbeemster assemblages, the Maximum and Minimum Range was calculated for each trait, if possible. A comparative assemblage was not found for each of the NMTs used in the Middenbeemster sample. Traits without a counterpart in another assemblage were excluded for this statistical test. The comparison between the Maximum and Minimum range was set up, because it was expected that mechanical NMTs would exhibit more variation than genetic NMTs between groups of the same ethnicity. It was hypothesised that the activities of these groups would vary more than their genes.

For the Maximum Range, the percentage data of all NMTs was entered in SPSS into one column. In the second column, the data was assigned its own group: 1=genetic, 2=mechanical, and 3=ambiguous. Then, the ANOVA test was applied to the data. The outcome was not statistically significant ($F=0.959$; $p=0.406$). A Tukey's HSD test was used to find means that are significantly different from each other. No statistical significance was found. For the Minimum Range, the percentage data of all NMTs was entered in SPSS into one column. In the second column, the data was assigned its own group: 1=genetic, 2=mechanical, and 3=ambiguous. Then, the ANOVA test was applied to the data. The outcome was not statistically significant ($F=0.847$; $p=0.448$). Both Maximum and Minimum Range Difference tests were repeated, without the Ambiguous category, since it was considered possible that this category could have obscured the results from the previous tests. The results were not significant for the Maximum Range Difference ($F=1.849$; $p=0.201$) or the Minimum Range Difference ($F=0.800$; $p=0.390$).

4.4. Sex

In the following section it will be determined whether statistical differences between the sexes will be significant. For convenience, the

probable males were grouped with the males (total n=45) and the probable females were grouped with the females (total n=48). For traits that were scored for both the right and left side, the highest score was used, since this value shows the maximum expression of the genetic potential of that specific trait. In Table 4.1. the frequency of NMTs per combined sex category (male+probable male; female+probable female) has been noted, in percentages.

Table 4.1. NMTs per combined sex category (M+PM and F+PF), in percentages.

Non-Metric Traits	**Total *n* of individuals % *n*=93**		**Male + Prob. Male % *n*=45**		**Female + Prob. Female % *n*=48**	
	L	***R***	***L***	***R***	***L***	***R***
Metopic suture	49.5		71.1		29.2	
Supraorb. Foramen	48.4	50.5	46.7	48.9	54.2	50.0
Auditory exostosis	11.8	22.6	6.7	15.6	16.7	29.2
Mastoid foramen	59.1	61.3	66.7	60.0	50.0	60.4
Bregmatic ossicle	0.0		0.0		0.0	
Parietal foramen	43.0		37.8		47.9	
Highest nuch. Line	37.6		42.2		33.3	
Double cond. fac.	15.1	14.0	17.8	15.6	12.5	12.5
Palatine torus	38.7		42.2		35.4	
Mylohyoid bridge	25.8	30.1	17.8	15.6	33.3	29.2

Mental spine	53.8		62.2		45.8	
Double atlas facet	52.7	51.6	57.8	55.6	47.9	47.9
Sacralisa-tion	15.1		17.8		12.5	
Sternal foramen	2.2		2.2		2.1	
Os acromiale	7.5	7.5	4.4	4.4	9.2	9.2
Supracond. process	0.0	0.0	0.0	0.0	0.0	0.0
Septal aperture	6.5	4.3	2.2	2.2	10.4	6.3
Trochlear spur	52.7	46.2	53.3	55.6	52.1	37.5
Third trochanter	16.1	18.3	15.6	17.8	16.7	18.8
Poirier's facet	15.1	6.5	22.2	6.7	8.3	6.3
Supernu-merary rib	6.5		8.9		4.2	
Acetabular crease	0.0	0.0	0.0	0.0	0.0	0.0
Vastus notch	2.2	0.0	2.2	0.0	2.1	0.0
Tibial squat. fac.	47.3	47.3	48.9	48.9	45.8	45.8
Talar squat. fac.	14	17.2	13.3	13.3	14.6	20.8
Double calc. fac.	51.6	53.8	55.6	53.3	47.9	54.2

All percentage data for both sexes was entered into one column. In the second column, the data was assigned its sex, male=1, female=2. For this data, a t-test was applied, because two groups were represented. The results were not significant (F=1.839; p=0.508). The test was repeated for the sex categories, using separate NMT categories: in the first test, only genetic NMTs were used, in the second, only mechanical NMTs, and in the third test, the ambiguous NMTs were used. For these tests, an Independent Samples t-test was used. Using only genetic NMTs for Sex, statistical significance was not found (t=-0.328; P=0.749). Using mechanical NMTs only, statistical significance was not found (t=0.544; P=0.596). When only ambiguous NMTs were used, statistical significance was not found (t=0.163; P=0.873).

4.5. Age

In the following section it will be assessed whether a statistically significant difference is present between the different age groups. The five individuals aged as Middle/Old Adult were excluded for this test. For traits that were scored for both the right and left side, the highest score was used. Statistics for the NMTs per age category were calculated using an ANOVA test, since four age groups were represented. In Table 4.2. the frequency of NMTs per age category (Early Young Adult; Late Young Adult; Middle Adult; Old Adult) has been noted, in percentages.

Table 4.2. NMTs per age category (Early Young Adult; Late Young Adult; Middle Adult; Old Adult), in percentages.

Non-Metric Traits	EYA % *n*=17		LYA % *n*=26		MA % *n*=30		OA % *n*=15	
	L	*R*	*L*	*R*	*L*	*R*	*L*	*R*
Metopic suture	47.1		50.0		40.0		73.3	
Supraorb. foramen	41.2	41.2	53.8	57.7	50.0	40.0	46.7	60.0
Auditory exostosis	29.4	23.5	7.7	29.4	6.7	6.7	12.3	20.0
Mastoid foramen	52.9	58.8	61.5	61.5	50.0	56.7	73.3	66.7
Bregmatic ossicle	0.0		0.0		0.0		0.0	
Parietal foramen	41.2		34.6		34.6		40.0	
Highest nuch. line	17.6		42.3		42.3		66.7	
Double cond. fac.	5.9	0.0	15.4	15.4	20.0	20.0	20.0	13.3
Palatine torus	41.2		23.1		50.0		46.6	
Mylohyoid bridge	17.6	47.1	46.2	42.3	23.3	10.0	13.3	33.3
Mental spine	88.2		46.2		40.0		53.3	
Double atlas facet	64.7	64.7	57.7	53.8	56.7	56.7	33.3	33.3
Sacralisa-tion	23.5		3.8		16.7		20.0	
Sternal foramen	0.0		3.8		3.3		0.0	

Os acromiale	0.0	0.0	11.5	9.2	10.0	6.7	6.7	0.0
Supracond. process	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Septal aperture	11.8	11.8	7.7	0.0	3.3	3.3	6.7	0.0
Trochlear spur	47.1	23.5	46.2	50.0	73.3	50.0	46.7	60.0
Third trochanter	11.8	29.4	11.5	11.5	16.7	16.7	26.7	26.7
Poirier's facet	12.8	17.6	45.4	15.4	20.0	23.3	13.3	13.3
Supernum. rib	5.9		3.8		10.0		6.7	
Acetabular crease	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Vastus notch	0.0	0.0	3.8	0.0	0.0	0.0	6.7	0.0
Tibial squat. fac.	47.1	29.4	50.0	50.0	56.7	56.7	33.3	26.7
Talar squat. fac.	23.5	23.5	3.8	3.8	10.0	20.0	33.3	26.7
Double calc. facet	52.9	52.9	38.5	38.5	60.0	60.0	46.7	60.0

All percentage data for each NMT was entered into one column. In the consecutive columns the data per Age Category was entered: 1=Early Young Adult; 2=Late Young Adult; 3=Middle Adult; 4=Old Adult. No statistical significance was found for the NMTs per Age category (F=0.040; P=0.989). A Tukey's HSD test showed that there was barely any difference within and between the different age groups. For each compared category the P-value was at least 0.989. These high P-values indicate that there was practically no difference within and between the groups. The test was

repeated in order to assess whether a difference was present when the three NMT categories were analysed separately. When only genetic NMTs were used, no statistical significance was reached (F=0.060; P=0.980). When only mechanical NMTs were used, no statistical significance was found (F=0.045; P=0.987). When only ambiguous NMTs were used, no statistical significance was found (F=0.235; P=0.871).

4.6. Comparative Assemblages

In the following tables, the frequency of cranial and post-cranial NMTs in the Middenbeemster sample and the comparative assemblages will be displayed (see Fig. 4.5. and Fig. 4.6.).

Some notable percentages were encountered for a few NMTs. Both Middenbeemster and the comparative assemblages showed a high to very high percentage of the mastoid foramen. A very low percentage of the bregmatic ossicle was encountered in all assemblages, including Middenbeemster. The Middenbeemster assemblage showed a higher percentage in the double condylar facet compared to the two other assemblages (29.1% in Middenbeemster vs. 5.1% in the Amsterdam assemblage and 16.2% in the Terry assemblage). A high percentage of tibial squatting facets was encountered in the Middenbeemster assemblage, compared to the Barton assemblage (47.3% vs. 3.5%).

NMTs					Nordic						
Cranial	MB	A'dam	Terry	Hallgr	Nor	Den	Ice	Green	UK	Barton	Other
Metopic suture	8.6	11.4	7.2	-	12.0	9.1	4.9	3.9	9.0	3.7	-
Supraorb. foramen	50.00	67.7	40.3	31.7	-	-	-	-	-	-	-
Auditory exostosis	34.4	0.0	-	23.2	0.0	0.0	0.0	0.0	0.0	-	-
Mastoid foramen	59.1	77.1	80.9	23.0	50.1	48.7	44.3	31.4	34.0	-	-
Bregmatic Ossicle	0.0	2.0	-	-	1.4	4.1	0.0	0.0	0.3	0.4	-
Parietal foramen	43.0	63.0	50.0	32.8	58.1	49.0	51.1	59.8	56.0	-	-
H. nuchal line	37.6	28.0	-	-	57.0	30.0	62.4	34.5	34.5	-	-
Condylar facet	29.1	5.1	16.2	-	-	-	-	-	-	-	-
Palatine torus	38.7	4.7	23.7	26.4	43.2	28.8	51.4	47.8	27.0	-	-
Mylohyoid bridge	28.0	-	22.3	19.6	-	-	-	-	-	-	-
Mental spine.	53.8	-	78.4	-	-	-	-	-	-	-	-

Fig. 4.5. Cranial NMTs in Middenbeemster and comparative assemblages, in percentages.

NMTs Post-cranial	MB	A'dam	Terry	Hallgr.	Nordic					Barton	Other
					Nor	Den	Ice	Green	UK		
Double atlas facet	52.2	-	-	-	-	-	-	-	-	-	-
Sacralisation	15.1	-	-	-	-	-	-	-	-	-	-
Sternal foramen	2.2	-	-	-	-	-	-	-	-	-	4.5
Os acromiale	7.5	-	-	-	-	-	-	-	-	2.7	5.4
Supracond. process	0.0	-	-	-	-	-	-	-	-	1.1	-
Septal aperture	10.8	-	-	-	-	-	-	-	-	4.6	4.3
Trochlear spur	49.5	-	-	-	-	-	-	-	-	-	-
Third trochanter	17.2	-	-	-	-	-	-	-	-	-	-
Poirier's facet	10.8	-	-	-	-	-	-	-	-	-	-
Supernum. rib	6.5	-	-	-	-	-	-	-	-	-	-
Acetabular crease	0.0	-	-	-	-	-	-	-	-	-	-
Vastus notch	1.1	-	-	-	-	-	-	-	-	2.8	-
Tibial sq. facet	47.3	-	-	-	-	-	-	-	-	3.5	-
Talar sq. facet	15.6	-	-	-	-	-	-	-	-	-	11.0
Calcaneal facet	52.7	-	-	-	-	-	-	-	-	-	-

Fig. 4.6. Post-cranial NMTs in Middenbeemster and comparative assemblages, in percentages.

CHAPTER 5. DISCUSSION

5.1. Objectives and Intrapopulational Findings

The first objective of this research was to assess whether a statistically significant difference was present in the occurrence and frequency of the selected NMTs between males or females, and between the different age groups. The second objective was to gain more insight in the distinction between the mechanical, genetic, and ambiguous NMT categories.

The main findings of this study are that there is neither a statistically significant difference in the prevalence of either genetic, mechanical, or ambiguous NMTs between males and females, nor between the different age categories in the Middenbeemster assemblage. Although it is apparent that the lack of statistical significance is partially related to the small sample size, it can also be interpreted that especially the NMTs with a genetic or ambiguous cause are evenly spread over the population, regardless of age or sex. The lack of difference between males and females with regard to the prevalence of NMTs is in accordance with results from anthropological research and literature reviews, which generally show no or rarely any sexual dimorphism in NMTs (Hauser and DeStefano 1989). The same is the case for the lack of difference between the age categories. Although it has been suggested that age can affect the incidence of certain NMTs, no convincing results have yet been obtained (Hauser and DeStefano, 1989).

Contrary to expectation, no difference between males and females was encountered in the prevalence of mechanical NMTs. A difference in the prevalence of mechanical NMTs was expected between males and females, as induced by a sexual division of labour, or professions that were typically occupied by either males or females. Although the influence of a small sample size cannot be excluded, these results may also indicate that both sexes performed comparable habitual physical labour,

resulting in skeletally indistinguishable NMTs. Likewise, no difference in the prevalence of mechanical NMTs was found between the different age categories either. An increased number of mechanical NMTs was expected in the two older age categories of the Middle and Old Adults, when compared to younger individuals in the Early and Late Young Adult categories. Once again, these results may be affected by the small sample size. Further research with an enlarged sample may prove if this observed difference is indeed related to small sample size or whether an actual significant difference is present between the age categories. Including adolescents and/or older children may elucidate if, and to what extent, mechanical NMTs are present in the skeletons of sub-adult individuals, who are less likely to have performed lengthy, habitual physical activity.

5.2. Objectives and Interpopulational Findings

Comparative assemblages have been employed in order to find comparative data for the selected NMTs from the Middenbeemster sample. It was hypothesised that we would see more variation in mechanical NMTs than in genetic NMTs between assemblages of the same ethnicity, since it was expected that the activities of these different groups would vary more than their genes. The proposed null hypothesis was therefore that we would see no difference between mechanical and genetic NMTs between different assemblages. Finding sufficient comparative assemblages proved harder than initially anticipated. For 18 out of the 26 Middenbeemster NMTs one or more comparative assemblages were found. It proved especially hard to find comparisons in other assemblages for post-cranial NMTs.

The results from this research have not been able to reject the null hypothesis, since no statistically significant differences were encountered between the Middenbeemster sample and the comparative assemblages. By and large, the percentages for the Middenbeemster NMTs fall within the range of variation. For six NMTs from the Middenbeemster sample, only one comparative assemblage could be found. Although the Middenbeemster percentages for these traits were within the same range

as those of the comparative assemblages, these results lack robustness because of the meagre number of comparative assemblages.

5.3. Analysis of the Results

At the commencement of this study, more variation in mechanical NMTs than in genetic NMTs between different assemblages was anticipated, since it was thought that activities would vary more between groups than their genes. However, no statistically significant differences were found between the Middenbeemster and comparative samples, and thus the null hypothesis could not be rejected. Therefore, we should consider that the null hypothesis might be true: it may be possible that no differences exist between the NMT categories, since there is no difference in heritability or activity susceptibility. This might suggest that NMTs occur arbitrarily in an assemblage and are not at all affected by genetic predisposition or habitual mechanical activities. This would make the proposed categorical distinction completely void.

However, it is unlikely that there are no differences between the different NMT categories. Numerous studies have indicated that repetitive mechanical actions affect the bone structure and result in skeletal activity markers, such as the tibial and talar squatting facet (e.g. Barnett 1954, Singh 1959, Singh 1963). Other NMTs, especially cranial, have a high heritable component, such as the metopic suture and sternal foramen (Hauser and DeStefano 1989, Jones *et al.* 2007). Although this study has not been able to find differences between mechanical and genetic NMTs, future research with a larger sample size will contribute to the clarification of NMT causes.

5.4. Limitations

To provide an adequate recording and scoring system for the selected NMTs, I employed a list derived from the scoring system used by Hauser and DeStefano (1989), Buikstra and Ubelaker (1994), and Finnegan (1978). For some traits however, a new or adapted scoring and/or recording

system had to be adopted. The use of a personalised scoring and recording system has proved very beneficial for the specific needs of this research. However, matters became rather complex when working on the statistical analyses and comparative assemblages. Since no standard scoring list exists yet, most researchers use a personalised scoring system, which differs per study and per researcher. The lack of a standardised scoring system is a complicating factor when one wants to compare different assemblages, which are all analysed using different scoring systems. This was also the case in this research. It proved difficult to find a sufficient number of assemblages that used comparable NMTs. When matching NMTs were found, it was often unclear which scoring system was used. For instance, the metopic suture is a trait that is often recorded in non-metric studies. However, it is rarely clarified when it is exactly counted as Present. In this research, the metopic suture was scored as Present when a trace at glabella was visible, whereas in other studies a complete frontal suture is required to be scored as Present. To meet this problem and be able to make a valuable comparison between Middenbeemster and the other assemblages, it was decided to merge the separate scores per trait of the Middenbeemster individuals into one for the benefit of the statistical analyses (i.e. the detailed, threefold scorings for auditory exostosis were all considered as Present). For the sake of this research, it was decided that if no explanation of the exact scoring method was provided for the NMTs in the comparative assemblages, nor could it be retrieved, the traits were assumed to be Present, without a further multilevel subdivision. Adapting the scoring system to better match the comparative assemblages was not feasible due to limitations in time.

An additional problem was the rarity of some NMTs in the Middenbeemster assemblage. A number of NMTs was encountered so infrequently that the detailed scoring proved redundant. For these traits it was decided to combine the separate scores. For instance, the separate scores of pinhole or true perforation for the sternal foramen and septal aperture were merged and both considered as Present (see also chapter

3.6.1. Statistical Notes). The rare occurrence of certain traits is imputed to the small sample size. The haziness about the exact cause of some NMTs posed another serious limitation. For the benefit of this research, it was decided that if scientific consensus was reached for the cause of a NMT, it was denoted as being either genetic or mechanical. However, for a vast amount of NMTs, causes are obscure or are at this moment too debated to fall into a distinct category. For this reason, the third ambiguous category was created, to harbour these precarious NMTs.

An enlarged sample size, additional comparative assemblages and a more standardised scoring system would be likely to resolve the complications mentioned above, but were beyond the scope of the research.

5.5. Future Research and Recommendations

A novelty of this research is the subdivision of NMTs into three categories: genetic, mechanical, and ambiguous. Despite some problems with this distinction (see chapter 5.4. Limitations), the application of this more detailed method may prove valuable for future research.

In current osteological research no distinctions are made with regard to NMTs with different causes. Despite clear differences in cause, the different categories of NMTs are lumped together. For a basic skeletal report, or research that is not directly concerned with this topic, the use of different NMT categories is not necessarily of added value. However, for specific studies, the employment of different categories of NMTs can certainly add valuable insights to the research. Beside the fact that the observation of NMTs, even on fragmented or damaged skeletal material, is an easy and inexpensive method, NMTs can also supply a refreshing view on the daily life of past people. Mechanical NMTs are clear and easily observed skeletal markers when one wants to study the influence of habitual physical activities. A deeper understanding of mechanical NMTs can provide insight in the occupational activities of the individuals under study. The study of genetic NMTs can contribute to the establishment of

genetic relatedness and familial bonds within a population or assemblage, especially when the retrieval of DNA is not possible due to poor preservation of the material.

Despite these benefits, NMTs have never truly been a major focus in bioarchaeological research. The ambiguous nature of many traits is one of the main reasons that different categories of NMTs are usually not wielded. Further research may bring clarity about the aetiology of NMTs, enabling a more precise and detailed study into this field. I argue that the implication of a more detailed subdivision in NMTs in both osteological research and standard skeletal reports will aid in the research into the causes of NMTs, with special regard to the clarification of NMTs in the ambiguous category.

Once the archival research into the historical parish data from Middenbeemster has been concluded, it can be used to help better understand the causes of different NMTs. It may be possible to answer if certain mechanical NMTs are more prevalent within certain social or professional groups or whether certain genetic NMTs show a higher prevalence in genetically related individuals, based on familial bonds recorded from the historical data.

CHAPTER 6. CONCLUSION.

The main research aim of this thesis was to determine if a significant difference in the frequency of mechanical NMTs compared to genetic NMTs was present, within the Middenbeemster sample, and among comparative samples of the same ethnicity. In order to answer this question, 26 cranial and post-cranial NMTs were examined in 93 adult skeletons (45 males and 48 females) from the Middenbeemster assemblage, employing an adapted scoring system. This study has found that there are no statistically significant differences between the frequency of the selected NMTs between males and females. No statistically significant difference was found when comparing the different age categories either. It was also hypothesised that there would be more variation in mechanical NMTs than in genetic NMTs between assemblages of the same ethnicity, since it was expected that the activities of these groups would vary more than their genes. When comparing the Middenbeemster sample to the comparative assemblages, no statistically significant differences were encountered. The percentages for the Middenbeemster NMTs generally fell within the same range as those of the comparative assemblages.

The lack of a standardised scoring system posed a complicating factor when comparing different assemblages, which were analysed using different methods. The rare occurrence of a number of traits was imputed to the small sample size. The small number of comparative assemblages further complicated comparisons for the Middenbeemster data. Enlarged sample sizes, additional comparative assemblages, and a more standardised scoring system would probably resolve the beforementioned complications.

This study has introduced the novel application of subdividing NMTs into a mechanical, genetic, and ambiguous category. Current

osteological research does not distinguish between the different NMT categories, despite clear causal differences. I have argued that the employment of different categories can be of value to bioarchaeological research. Mechanical NMTs provide insight into occupational activities of past people, whereas genetic NMTs can be used to establish familial bonds. The implication of different categories into osteological research will aid in clarifying the aetiology of NMTs, especially the ambiguous ones.

After the conclusion of the archival research it may be possible to answer whether certain mechanical NMTs are more prevalent in certain social or professional groups. We might also be able to assess if genetic, highly heritable NMTs show a higher prevalence in genetically related individuals, based on familial bonds recorded from the parish records.

Abstract

Skeletal non-metric traits (NMTs) are minor morphological variants that are often used by osteoarchaeologists to determine genetic affiliation between past populations (biodistance). Some NMTs are heavily affected by environmental factors, especially habitual physical activities, whereas others have a genetic cause. This study introduces the novel application of subdividing NMTs into a mechanical, genetic, and ambiguous category, to elucidate traits of different heritability. This method is applied to a sample of 93 well-preserved adult skeletons from the 17th-19th century AD cemetery of Middenbeemster, the Netherlands. Twenty-six cranial and post-cranial skeletal NMTs were examined to determine: 1) whether significant differences in NMTs between males and females, and different age groups were present, 2) whether significant differences in mechanical NMTs versus genetic NMTs were present in the Middenbeemster sample, and 3) whether there was more variation in mechanical versus genetic NMT frequency between Middenbeemster and comparative groups of the same ethnicity. It is expected that mechanical NMTs would exhibit more variation than genetic NMTs, since it is thought that activities vary more between groups than their genes. No statistically significant differences in NMT frequency were present between males and females, or among age categories. No statistically significant differences were observed between the genetic and mechanical NMT categories in the Middenbeemster sample. Finally, no significant differences were encountered when comparing Middenbeemster to comparative assemblages. The results are affected by a small sample size, and the lack of comparative samples with frequency data for many NMTs. Future research using this categorisation can provide insight in highly heritable NMTs, which will improve the accuracy selection of biodistance studies, and traits that are more mechanically affected, for use in past activity reconstruction.

Appendix I. Description of Non-Metric Traits

Cranial Non-Metric Traits

Metopic suture *(sutura metopica)*

The metopic suture is located on the **frontal bone**, on the anterior cranium. At birth the frontal bone consists of two halves, separated by a suture. If this suture persists into adulthood it is named a metopic suture. A metopic suture can range from a small trace at glabella, to a suture halfway up the frontal bone, to a complete suture all the way up to the coronal suture (Hauser and De Stefano 1989).

Supraorbital foramen *(foramen supraorbitale)*

A supraorbital foramen can be found on the superior part of the **orbit**. A single foramen or multiple foramina may be present on or slightly above the supraorbital margin. It is only scored if the foramen is fully enclosed by bone (Hauser and De Stefano 1989).

Auditory exostosis *(exostosis auditivus)*

Auditory exostosis is located in the **external auditory meatus**. Bony deposits may be present in the external auditory meatus. It is scored as a spicule, occluding the auditory canal more than 1/3, or less than 1/3 (Hauser and De Stefano 1989).

Mastoid foramen *(foramen mastoideum)*

A mastoid foramen can form on the **mastoid process.** A single foramen or multiple mastoid foramina may be present on the occipital bone, temporal bone, or on the occipitomastoid suture. The mastoid foramen corresponds to the external aperture of the mastoid canal (Hauser and De Stefano, 1989).

Bregmatic ossicle *(ossicula bregmaticum)*

A bregmatic ossicle is located on the superior cranium, on the junction between the **frontal bone** and **parietal bones** (**bregma**). A bregmatic ossicle may present itself in varying sizes (Hauser and De Stefano 1989).

Parietal foramen *(foramen parietale)*

A parietal foramen is located on the superior **parietal bone** near or in the sagittal suture near obelion. A single foramen or bilateral foramina (rarely more) may pierce the parietal bone. A parietal foramen is only scored when it completely pierces the parietal bone (Hauser and De Stefano 1989).

Highest nuchal line *(linea nuchalis suprema)*

The highest nuchal line is a bilateral extension of the external occipital protuberance (**inion**) and is located on the inferior/posterior side of the **occipital**. The highest nuchal line originates from inion's upper end and curves towards both sides (Hauser and De Stefano 1989).

Double condylar facet *(facies condylaris bipartita)*

The double condylar facet is located on the two **occipital condyles**, on the inferior occipital bone, one on each side of the foramen magnum. The occipital condyles show a wide range of variation in shape and size. It may be divided partially or completely into an antero-medial and a postero-lateral half. It is scored as present, when two separate facets are observed (Hauser and De Stefano 1989).

Palatine torus *(torus palatinus)*

A palatine torus can be present on the inferior palate of the **maxilla**. The palatine torus is a bony protuberance on the midline of the maxillary palate. It may be a mere trace, or extend partially or completely over the palatine midline. It is palpable in some living individuals (Hauser and De Stefano 1989).

Mylohyoid bridge *(ponticulum mylohyoideus)*

The mylohyoid bridge is present at the mylohyoid groove on the medial sides of the **mandible**. The mylohyoid sulcus may be bridged by an osseous roof and is thus transformed into a canal. The bridge may be a trace, or a partial, or complete bridge (Hauser and De Stefano 1989).

Mental spine *(spina mentalis)*

The mental spine is located on the **mandible**. On the lingual surface of the mandible a tubercle may be present, sometimes taking the shape of a sharp spine. When present, it is scored as <2 mm or >2 mm (Hauser and De Stefano 1989).

Post-cranial Non-Metric Traits

Double atlas facet *(facies atlantis bipartita)*

The double atlas facet is located on the **atlas**. The superior atlas facets may be partially or completely divided into two separate facets (Finnegan 1978).

Sacralisation

Sacralisation occurs in the **sacrum**. Caudal border shifting creates varying degrees of assimilation or sacralisation of the last lumbar vertebra into the sacrum. The pedicles and transverse processes are transformed into sacral-like processes, with some degree of incorporation or articulation with the sacrum. Sacralisation of L5 (or L6 in the case of a supernumerary lumbar vertebra) can be unilateral or bilateral and symmetric or asymmetrical (Barnes 1994).

Sternal foramen (*foramen sternale*)

A sternal foramen is present on the distal part of the **sternum**. The foramen should fully penetrate the sternum to be scored as present. It may be a small pinhole or an actual perforation (Finnegan 1978).

Os acromiale (*os acromiale*)

An os acromiale is present on the **scapula**. It may appear as if the most superior tip of the acromion is missing, although the expected location of the acromion tip has a smooth surface. However, in the case of an os acromiale, it has actually never fused. In careful excavations, the separate acromion tip may be recovered (Finnegan 1978).

Supracondylar process (*processus supracondylaris*)

The supracondylar or supracondyloid process is located on the distal, medial **humerus**. The supracondylar process is a small, bony, hook-like process that arises above the medial epicondyle of the humerus. This NMT is rare (Finnegan 1978).

Septal aperture (*foramen septale*)

The septal aperture is located on the distal **humerus**. The bony septum between the olecranon and coronoid fossa is perforated. Caution should be taken not to confuse taphonomical damage for a septal aperture (Finnegan 1978).

Trochlear spur (*promontorium trochleum)*

The trochlear spur is located on the **ulna**. On the articular surface of the olecranon process of the ulna, a division may be observed in the trochlea. This division may be partial or complete (Finnegan, 1978).

Third trochanter (*throchanter tertius*)

The third trochanter is located on the anterior, proximal **femur,** at the superior crest of the gluteal line. With its rounded, oblong appearance, it resembles the lesser trochanter. It develops above or instead of the gluteal ridge (Finnegan 1978).

Poirier's facet (*facies Poirier*)

Poirier's facet is located on the **femur**. Poirier's facet is a noticeable, yet

slight, smooth bulging of the articular facet of the femoral head, towards the anterior portion of the femoral neck (Finnegan 1978).

Supernumerary rib (*costa additicius*)

A supernumerary rib can be present as a cervical or lumbar **rib**, or a supernumerary thoracic rib, and is located in the **thorax**. Supernumerary ribs may be uni- or bilateral.

Acetabular crease *(rimula acetabula)*

The acetabular crease is located in the **acetabulum.** Often a crease is located on the articular surface of the acetabulum, in the form of a line from the acetabular fossa to the border of the articular surface (Finnegan 1978).

Vastus notch *(incisura vastus)*

The vastus notch is located at the superolateral angle of the **patella**. It appears as a concavity at the site of the vastus lateralis tendon. The border of the vastus notch needs to be smooth to be scored as present (Finnegan 1978).

Tibial squatting facets *(facies tibialis subsido)*

The tibial squatting facet is present on the distal, anterior **tibia**, where it presents itself as a smooth, rounded depression, sometimes with eburnation, as the result of continuous squatting (Finnegan 1978).

Talar squatting facets *(facies talaris subsido)*

The talar squatting facet is located on the medial articular facet of the **talus**. It appears as an extension of the anterior trochlear margin (Finnegan 1978).

Double calcaneal facets *(facies calcaneus bipartitus)*

A double calcaneal facet is located on the inferior side of the **calcaneus**. The middle anterior facets are often fused to one oblong shaped facet, but

in some cases the facets are separated and thus double (Finnegan 1978).

Appendix II. Causes of Non-Metric Traits

Cranial Non-Metric Traits

Metopic Suture

Cause: genetic

The metopic suture is formed when, after the normal obliteration of the two halves of the frontal bone, the suture persists. The metopic suture is a hereditary trait, consisting of multiple additive genes (Hauser and DeStefano 1989).

Supraorbital Foramen

Cause: genetic

A supraorbital foramen is an external orifice formed by canals piercing the orbital roof and superciliary arch of the frontal bone. The supraorbital foramen or foramina suggest different growth patterns of nerves, vessels and other connective tissue. Supraorbital foramina have been observed in fetuses of 25 weeks in utero. This early manifestation, in combination with skeletal studies of families of known sex, age and cause, strongly suggest that this trait has a genetic background (Hauser and DeStefano 1989).

Auditory Exostosis

Cause: ambiguous

An auditory exostosis is a bony protrusion or outgrowth from the external auditory meatus, that can start to form after the formation of the tympanic bone has completed. In severe cases, the exostoses can grow so big that they occlude the meatus in such a high degree that it interferes with hearing. An auditory exostosis has a partial genetic predetermination, which can lead to tumorigenesis (formation of tumors), mostly after external irritation, such as continuous diving in cold or salt water ("surfer's ear") (Hauser and DeStefano 1989).

Mastoid Foramen

Cause: genetic

The mastoid foramen is the external aperture of the mastoid canal that transmits a vein to the sigmoid sinus and the dura mater. The position, size and number of the foramen can vary. It can be located on the temporal, occipital and/or occipitomastoid suture. In general, the mastoid foramen is a bilaterally occurring trait. If unilateral, there is a preference for the right side. The mastoid foramen has a genetic cause. Complete absence of a mastoid foramen is rare. Age-related change does not occur (Hauser and DeStefano 1989).

Bregmatic Ossicle

Cause: ambiguous

The bregmatic ossicle is a Wormian bone (supernumerary ossicle) and its formation is associated with insufficient suture closure. For some part the bregmatic ossicle has a genetic background and is moderately inheritable, but it is also partially influenced by environmental factors, such as cranial and/or brain growth (Hauser and DeStefano 1989).

Parietal Foramen

Cause: genetic

The parietal foramen is formed when vessels perforate the lateral sides of the obelic fontanelle, thus giving rise to a parietal foramen which forms after the onset of ossification, usually around the seventh week in utero. It has been thought that particularly large foramina may be due to a defective ossification. The parietal foramen is thought to be inherited as an autosomal dominant trait, with varying expression. It has been shown to have a familial occurrence (Hauser and DeStefano 1989).

Highest Nuchal Line

Cause: mechanical

The highest nuchal line originates from the external occipital protuberance (inion) and curves bilaterally upward. Onset of the formation of the

highest nuchal line is in late infancy up to late adolescence. The highest nuchal line is a mechanical trait, by some associated with prolonged (hyper)activity from the neck muscles (Hauser and DeStefano 1989).

Double Condylar Facet

Cause: mechanical

The occipital condyles are located on both sides of the foramen magnum. Their shapes and sizes vary and can be partially or completely divided. The double condylar facet has a mechanical background: the division of the condyles is in most cases attributed to mechanical occipital stress (Hauser and DeStefano 1989).

Palatine Torus

Cause: ambiguous

The palatine torus can form when the soft, cancellous bone of the midpalatal suture is replaced by bone with a cortex and medullary cavities, in the first years of life. A palatine torus can also be formed, when the palate is irritated or subdued to mechanical stress, for instance during the chewing of tough or hard food sources. The palatine torus has an ambiguous cause: some familial occurrence has been observed, especially in monozygotic twins. On the other side, the palatine torus has been associated with functional activities (mastication). It has been suggested that a genetically determined strong osseous response to irritation, can lead to the formation of a palatine torus (Hauser and DeStefano 1989).

Mylohyoid Bridge

Cause: genetic

The mylohyoid bridge is a bony structure that bridges the mylohyoid canal that transmits the mylohyoid nerve and artery. The canal can be partially or completely bridged. The mylohyoid bridge is considered an inherited trait with a variable range (Kaul and Pathak, 1984). Regional and group variability patterns suggest a genetic background (Hauser and DeStefano 1989).

Mental Spine

Cause: ambiguous

The mental spine is located on the lingual surface of the mandible and can range in size from very small to very large (up to 7 mms). Very little research has been done on the mental spine. It has been suggested that it is a mechanical trait, which has developed a more outstanding appearance due to continuous mechanical stress on the geniohyoid muscle. Due to a limited amount of research, a genetic predisposition cannot be excluded completely (Hauser and DeStefano 1989).

Double Atlas Facet

Cause: mechanical

The superior articular facets of the atlas have a variety of shapes and sizes. The facets can be partially or completely divided.

The double atlas facet is a mechanical trait. The division of the articular facets is frequently attributed to mechanical stress on the atlas (Hauser and DeStefano 1989).

Sacralisation

Cause: ambiguous

Sacralisation occurs when the body and/or transverse processes of the fifth lumbar vertebra fuse partially or completely to the sacrum. Note that in this study, fusion between a supernumerary lumbar vertebra (L6) and the sacrum is also defined as sacralisation. It can have an unilateral or bilateral expression. Sacralisation has an ambiguous background. In some individuals, sacralisation is a congenital condition. It has also been suggested that fusion occurs to avoid a distorted balance, caused by the tendency of the pelvic girdle to shift forwards (Hayes 1921). Sacralisation is more frequent in older individuals. This may be associated with age-related ossifying structures or ossifying reactions due to heavy mechanical stress on the lower back. It should be noticed that sacralisation is often associated with pathological conditions and should not be confused for a NMT in those cases (Hayes 1921).

Sternal Foramen

Cause: genetic

A sternal foramen is a congenital oval fusion defect of the sternum. Pevenage *et al.* mention that a sternal foramen occurs in up to 6.7% of a contemporary autopsy population (Pevenage *et al.* 2002).

Os Acromiale

Cause: ambiguous

An os acromiale has an ambiguous cause. It can develop when the growth plates from the scapular acromion process fail to fuse, usually at the anterior side of the acromion. Continuous mechanical loading from a young age can also result in non-ossification of the acromion tip (Hunt and Bullen 2007; Fury 2012).

Supracondylar Process (*processus supracondylaris*)

Cause: genetic

The supracondylar process is a rare NMT. It has a congenital counterpart, but may be activated through continuous mechanical stress on the humerus (Mittal *et al.* 1978). It is believed that the supracondylar process represents a phylogenetic vestige of a supracondylar foramen, found in some animals. A solely genetic cause has not yet been confirmed. Aydinlioglu *et al.* (2010) found an incidence of 1.0% in a study of 903 adult individuals.

Septal Aperture

Cause: genetic

A septal aperture is a congenital oval fusion defect of the olecranon fossa of the humerus. Paraskevas *et al.* (2012) proposed a possible association between the occurrence of a septal aperture and a supracondylar process.

Trochlear Spur

Cause: ambiguous

The trochlear spur has an ambiguous cause, since it is has a congenital cause, but is also partially formed by habitual mechanical loading of the

olecranon fossa, through medial tension stress and ulnar traction (Gore *et al.* 1980).

Third Trochanter

Cause: mechanical

The third trochanter is an oblong, rounded tubercle, located on the medial superior femur, and can be either uni- or bilateral. It develops above or instead of the gluteal ridge (Finnegan 1978). Habitual mechanical activities are usually linked to the formation of a third trochanter. The gluteus maximus muscle may act as a primary factor governing third trochanter expression. Lozanoff *et al.* (1985) found that third trochanter incidence is associated with short femora displaying robust proximal diaphyses (Lozanoff *et al.* 1985).

Poirier's Facet

Cause: mechanical

Poirier's facet is a slight, smooth extension of the femoral head. It has been shown that a Poirier's facet can form when the thigh is exaggeratedly flexed. In this position the femur rubs against a slight projection of the acetabular margin. Odgers (1931) suggested that such an unnatural position can occur during sleep, when an individual lays full length, with the upper lower limb put forward, putting pressure on the observed region (Odgers 1931).

Supernumerary Rib

Cause: genetic

A supernumerary rib is any extra rib to the normal 12 pairs. They can occur uni- or bilaterally in the cervical region, as a supernumerary thoracic rib or in the lumbar region. Sometimes complete ribs are formed, whereas other times only rudimentary costal heads appear. Supernumerary ribs have a genetic basis. This occurs when the transverse process of a vertebra is associated with an independent costal centre, which may blend with it, or persist as a cervical, supernumerary thoracic or lumbar rib (Hayes

1921).

Acetabular Crease

Cause: genetic

The acetabular crease presents as a crease or fold on the articular surface of the acetabulum. The acetabular crease has a genetic background, since it has been found in both prenatal fetuses as well as in neonates. Note that the acetabular crease is not the result of a faulty fusion (Finnegan 1978).

Vastus Notch

Cause: genetic

The vastus notch is a small concavity with smooth borders, on the superior, lateral angle of the patella. The causes of the vastus notch have not been extensively studied, but probably have a genetic background, since it is widely considered as a variation in tendon insertion (Anderson 2002).

Tibial Squatting Facet

Cause: mechanical

A tibial squatting facet appears as a smooth, round or oval facet on the distal, anterior tibia. The size of the facet can be small or medium, although (very) large squatting facets are known as well. The facets appear when various joints are habitually squeezed together, bringing bones into contact with another, that otherwise would not, resulting in a remodeling of the bone into squatting facets (Finnegan 1978).

Talar Squatting Facet

Cause: mechanical

The talar squatting facet is an extension of the medial articular facet. The extension can range from a slightly to a notably elongated articular facet. The facets appear when various joints are habitually squeezed together, bringing bones into contact with another, that otherwise would not, resulting in a remodeling of the bone into squatting facets (Finnegan

1978).

Double Calcaneal Facet

Cause: ambiguous

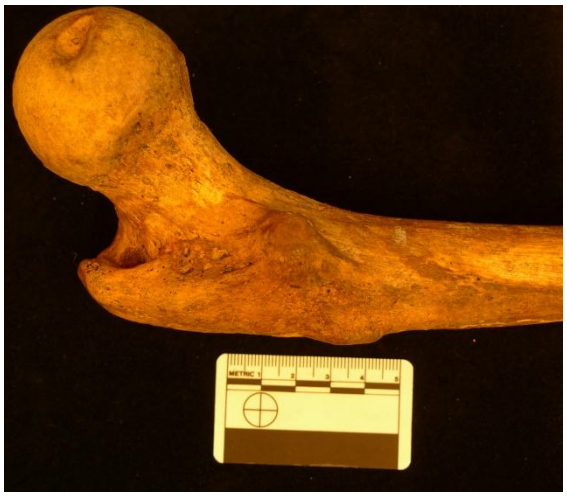
A double calcaneal facet is found on the inferior calcaneus, when the anterior and middle articular facet is separated into two discrete facets. Calcaneal facets have a partial genetic background and are possibly congenital. However, the effect of the postnatal environment has not been sufficiently studied to exclude these factors (Finnegan 1978).

Appendix III. Recording and Scoring Form

Non-Metric Traits	**Present Absent Unobser-vable**	**Additional descriptions, if Present**
Metopic suture	P, A, U ?	*Extent of suture:* Trace-partial-complete suture
Supraorbital foramen	P, A, U ?	-
Auditory exostosis	P, A, U ?	*Amount of occlusion:* Auditory canal occluded <1/3 - >1/3
Mastoid foramen	P, A, U ?	*Location of foramen/foramina:* Temporal-occipital-occipitomastoid suture
Bregmatic ossicle	P, A, U ?	-
Parietal foramen	P, A, U ?	*Location of foramen/foramina:* Left-right-bilateral
Highest nuchal line	P, A, U ?	*Size of nuchal line:* Trace-medium-strong-extreme
Double condylar facet	P, A, U ?	-
Palatine torus	P, A, U ?	*Extent of torus:* Trace-partial-complete
Mylohyoid bridge	P, A, U ?	*Extent of bridge:* Trace-partial-complete bridge
Mental spine	P, A, U ?	-
Double atlas facet	P, A, U ?	*Character of facet:* Joined-separated
Sacralisation	P, A, U ?	*Character of fusion:* L5/S1-L6/S1-right side-left side
Sternal	P, A, U ?	*Size of foramen:*

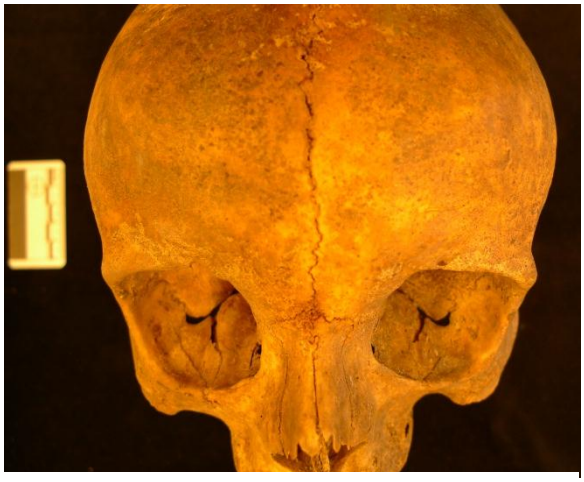
foramen		Pinhole-true perforation
Os acromiale	P, A, U ?	-
Supracondy-lar process	P, A, U ?	-
Septal aperture	P, A, U ?	*Size of aperture:* Pinhole-true perforation
Trochlear spur	P, A, U ?	*Extent of spur:* Partial-complete division
Third trochanter	P, A, U ?	-
Poirier's facet	P, A, U ?	-
Supernume-rary rib	P, A, U ?	*Location of rib:* Cervical left/right-thoracic left/right
Acetabular crease	P, A, U ?	-
Vastus notch	P, A, U ?	-
Tibial squatting facet	P, A, U ?	*Size of facet:* Small-medium-large facet
Talar squatting facet	P, A, U ?	-
Double calcaneal facet	P, A, U ?	-

Appendix IV. Pictures of Non-Metric Traits

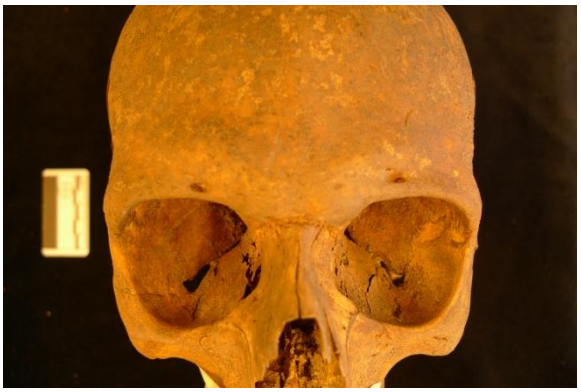


A1.Third trochanter (L): S487V1096

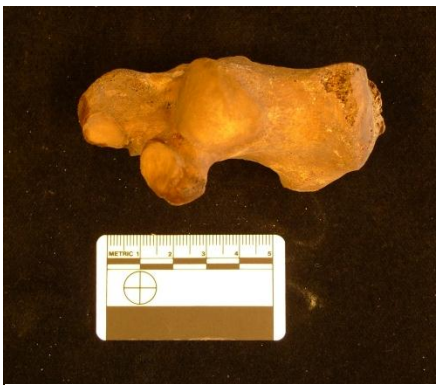
A2. Parietal foramen (bilateral): S126V0184



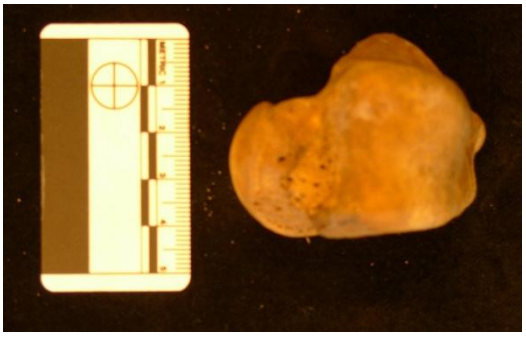
A3. Metopic suture: S401V0876



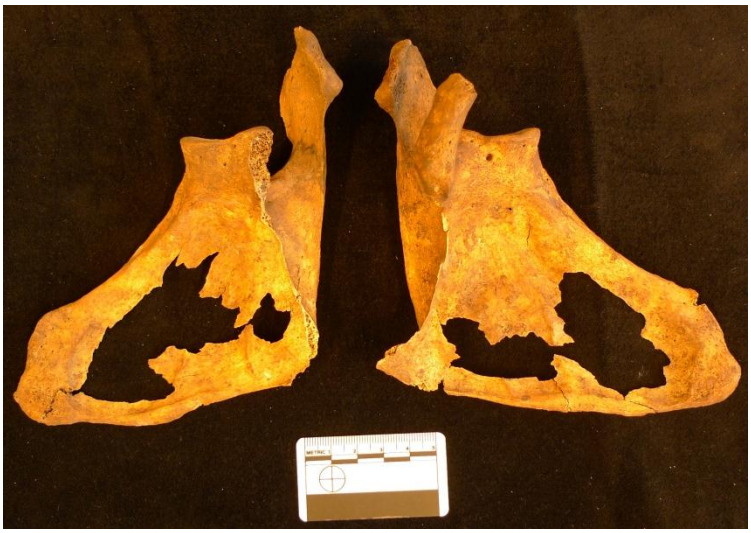
A4. Supraorbital foramen (L+R): S427V0983



A5. Double calcaneal facet (L): S488V1037

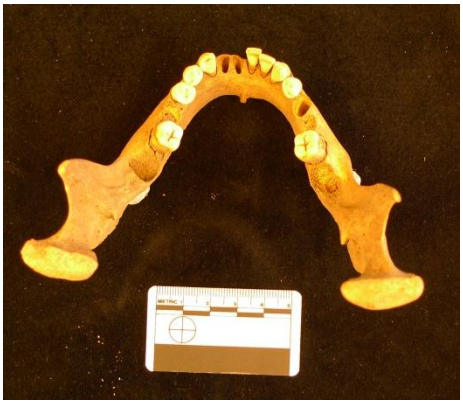


A6. Talar squatting facet (R): S476V1054

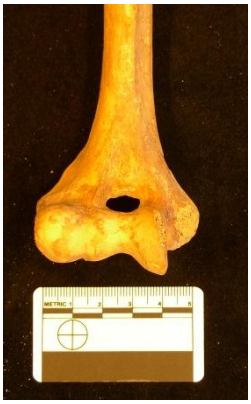


A7. Os acromiale (L+R): S088V0094

A8. Sacralisation of L6: S468V0735

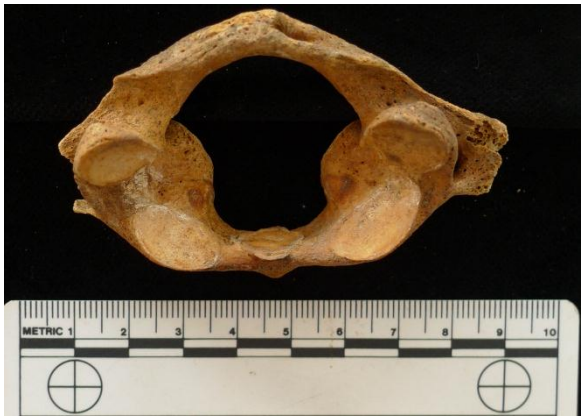


A9. Mental spine: S149V0280

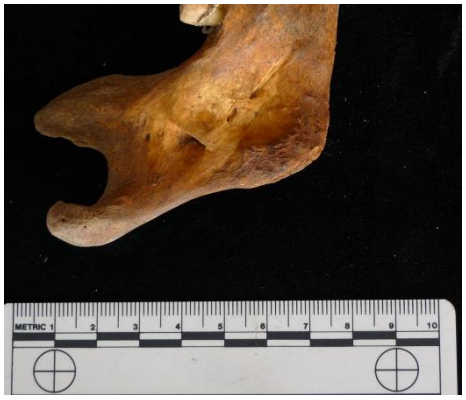


A10. Septal aperture: S149V0280

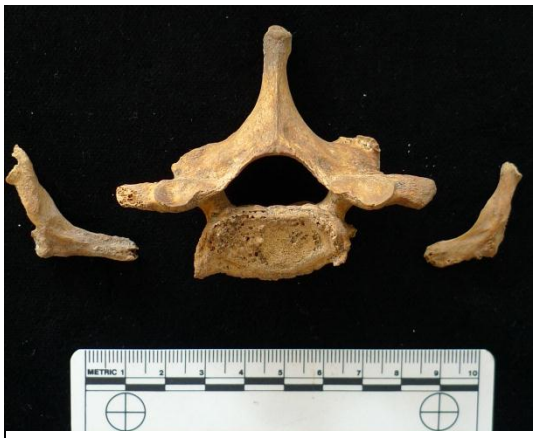
A11. Sternal foramen: S149V0280



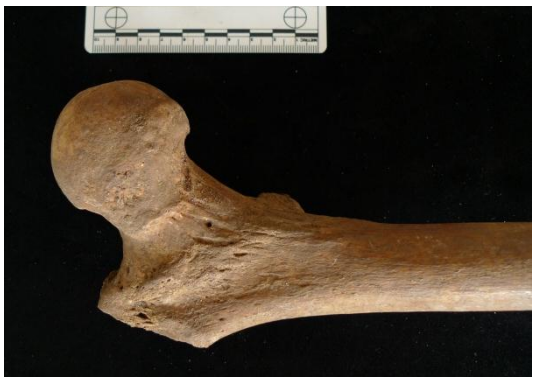
A12. Double atlas facet: S337V0714



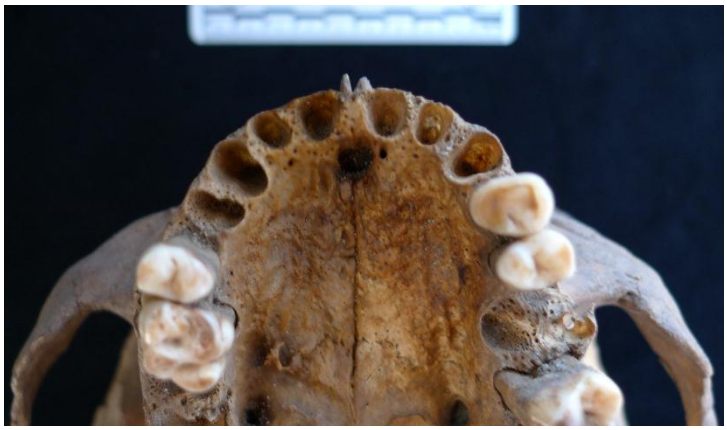
A13. Mylohyoid bridge (L): S404V1134.



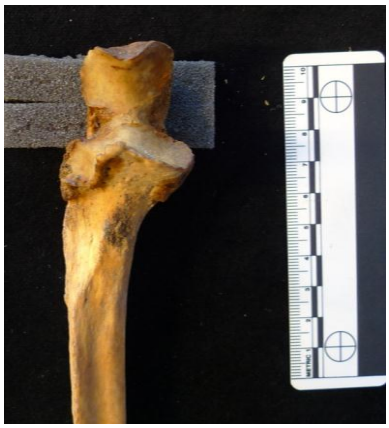
A14. Supernumerary rib on C7: S294V0487



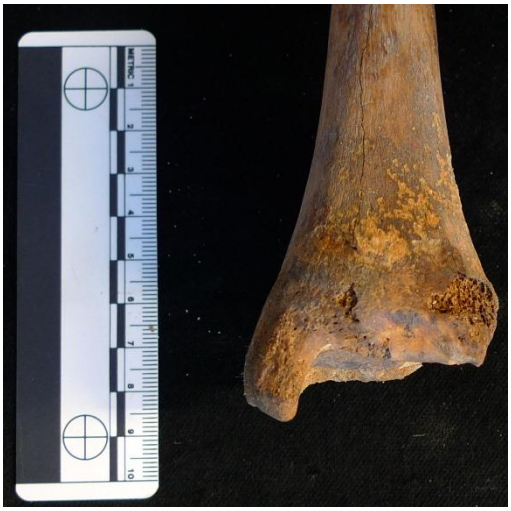
A15. Poirier's facet (R): S497V1095



A16. Palatine torus: S368V0794

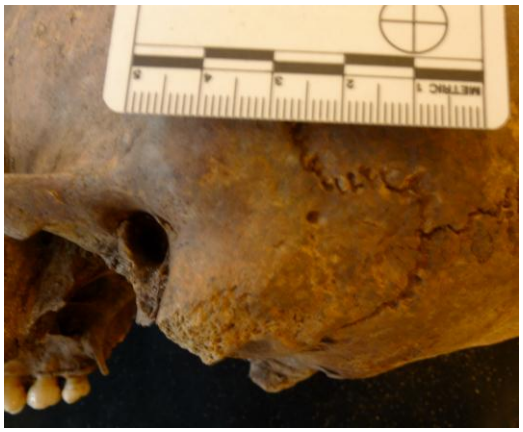


A17. Trochlear spur (R): S374V0891



A18. Tibial squatting facet (L): S481V1046

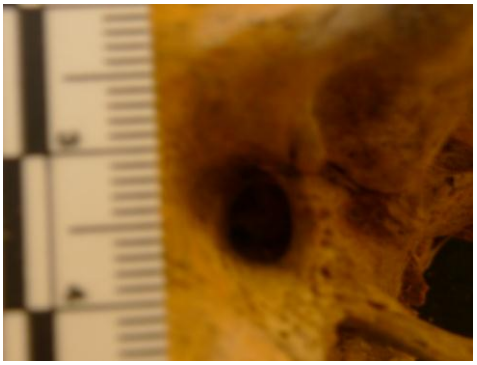
A19. Highest nuchal line: S344V0730



A20. Mastoid foramen (L): S198V0601

A21. Double condylar facet (R): S285V0452

A22.Vastus notch (L): S064V0050



A23. Auditory exostosis (R): S468V1009

A23a. Due to the poor visibility of the exostosis in A23, an individual with extreme auditory exostosis has been added, from the Neolithic site of Çayönü and Aşıklı, Anatolia.
Source: Özbek 2012, Fig. 3.

Appendix V. Database: Frequency of NMTs in Males and Females, in Percentages.

Non-Metric Traits	Total *n* of individuals % *n*=93		male + prob. male % *n*=45		female + prob. female % *n*=48	
	L	*R*	*L*	*R*	*L*	*R*
Metopic suture	49.5		71.1		29.2	
Supraorb. Foramen	48.4	50.5	46.7	48.9	54.2	50.0
Auditory exostosis	11.8	22.6	6.7	15.6	16.7	29.2
Mastoid foramen	59.1	61.3	66.7	60.0	50.0	60.4
Bregmatic ossicle	0.0		0.0		0.0	
Parietal foramen	43.0		37.8		47.9	
Highest nuch. Line	37.6		42.2		33.3	
Double cond. fac.	15.1	14.0	17.8	15.6	12.5	12.5
Palatine torus	38.7		42.2		35.4	
Mylohyoid bridge	25.8	30.1	17.8	15.6	33.3	29.2
Mental spine	53.8		62.2		45.8	
Double atlas facet	52.7	51.6	57.8	55.6	47.9	47.9
Sacralisa-tion	15.1		17.8		12.5	

Sternal foramen	2.2		2.2		2.1	
Os acromiale	7.5	7.5	4.4	4.4	9.2	9.2
Supracond. process	0.0	0.0	0.0	0.0	0.0	0.0
Septal aperture	6.5	4.3	2.2	2.2	10.4	6.3
Trochlear spur	52.7	46.2	53.3	55.6	52.1	37.5
Third trochanter	16.1	18.3	15.6	17.8	16.7	18.8
Poirier's facet	15.1	6.5	22.2	6.7	8.3	6.3
Supernu-merary rib	6.5		8.9		4.2	
Acetabular crease	0.0	0.0	0.0	0.0	0.0	0.0
Vastus notch	2.2	0	2.2	0.0	2.1	0.0
Tibial squat. fac.	47.3	47.3	48.9	48.9	45.8	45.8
Talar squat. fac.	14	17.2	13.3	13.3	14.6	20.8
Double calc. fac.	51.6	53.8	55.6	53.3	47.9	54.2

Appendix VI. Database: Frequency of NMTs per Age Category, in Percentages.

Non-Metric Traits	EYA % *n*=17		LYA % *n*=26		MA % *n*=30		OA % *n*=15	
	L	*R*	*L*	*R*	*L*	*R*	*L*	*R*
Metopic suture	47.1		50.0		40.0		73.3	
Supraorb. foramen	41.2	41.2	53.8	57.7	50.0	40.0	46.7	60.0
Auditory exostosis	29.4	23.5	7.7	29.4	6.7	6.7	12.3	20.0
Mastoid foramen	52.9	58.8	61.5	61.5	50.0	56.7	73.3	66.7
Bregmatic ossicle	0.0		0.0		0.0		0.0	
Parietal foramen	41.2		34.6		34.6		40.0	
Highest nuch. line	17.6		42.3		42.3		66.7	
Double cond. fac.	5.9	0.0	15.4	15.4	20.0	20.0	20.0	13.3
Palatine torus	41.2		23.1		50.0		46.6	
Mylohyoid bridge	17.6	47.1	46.2	42.3	23.3	10.0	13.3	33.3
Mental spine	88.2		46.2		40.0		53.3	
Double atlas facet	64.7	64.7	57.7	53.8	56.7	56.7	33.3	33.3
Sacralisa-tion	23.5		3.8		16.7		20.0	
Sternal	0.0		3.8		3.3		0.0	

foramen								
Os acromiale	0.0	0.0	11.5	9.2	10.0	6.7	6.7	0.0
Supracond. process	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Septal aperture	11.8	11.8	7.7	0.0	3.3	3.3	6.7	0.0
Trochlear spur	47.1	23.5	46.2	50.0	73.3	50.0	46.7	60.0
Third trochanter	11.8	29.4	11.5	11.5	16.7	16.7	26.7	26.7
Poirier's facet	12.8	17.6	45.4	15.4	20.0	23.3	13.3	13.3
Supernum. rib	5.9		3.8		10.0		6.7	
Acetabular crease	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Vastus notch	0.0	0.0	3.8	0.0	0.0	0.0	6.7	0.0
Tibial squat. fac.	47.1	29.4	50.0	50.0	56.7	56.7	33.3	26.7
Talar squat. fac.	23.5	23.5	3.8	3.8	10.0	20.0	33.3	26.7
Double calc. facet	52.9	52.9	38.5	38.5	60.0	60.0	46.7	60.0

Note: Due to ambiguous results from the aging methods, 5 individuals fell in both the Middle and Old Adult age category. These individuals were excluded from this sample.

Appendix VII. Database: Frequency of NMTs in Young Age and Old Age Category, in Percentages.

Non-Metric Traits	Young Age Group (EYA + LYA) % *n*=43		Old Age Group (MA + OA + MA/OA) % *n*=50	
Metopic suture	48.8		50.0	
Supraorbital foramen	48.8	51.2	50.0	50.0
Auditory exostosis	16.3	20.9	8.0	24.0
Mastoid foramen	58.1	60.5	56.0	60.0
Bregmatic ossicle	0.0		0.0	
Parietal foramen	37.2		48.0	
Highest nuchal line	32.6		42.0	
Double condylar facet	11.6	9.3	18.0	16.0
Palatine torus	30.2		46.0	
Mylohyoid bridge	34.9	44.2	18.0	18.0
Mental spine	62.8		46.0	
Double atlas facet	60.5	58.1	46.0	46.0
Sacralisa-tion	11.6		18.0	

Sternal foramen	2.3		2.0	
Os acromiale	7.0	11.6	8.0	4.0
Supracondylar process	0.0	0.0	0.0	0.0
Septal aperture	9.3	4.7	4.0	2.0
Trochlear spur	46.5	39.5	60.0	50.0
Third trochanter	11.6	18.6	20.0	20.0
Poirier's facet	14.0	16.3	16.0	18.0
Supernumerary rib	4.7		8.0	
Acetabular crease	0.0	0.0	0.0	0.0
Vastus notch	2.3	0.0	2.0	0.0
Tibial squatting facet	48.8	41.9	46.0	52.0
Talar squatting facet	14.0	14.0	16.0	22.0
Double calcaneal facet	44.2	44.2	56.0	62.0

Appendix VIII. Database: Score per Individual.

Skeleton #	Sex	Age	Met. Sut.	Supraorbital For.		Auditory Exo.	
				L	*R*	*L*	*R*
S427V0938	M	LYA	A	P	P	P:< ⅓	P:< ⅓
S149V0280	PF	EYA	P:trace	A	P	A	A
S290V0472	M	EYA	P:trace	A	A	P:< ⅓	P:< ⅓
S358V0763	F	MA	A	A	A	U	P:< ⅓
S525V1119	PM	OA	A	P	P	A	A
S473V1003	M	LYA	P:trace	P	A	A	A
S064V0050	PM	LYA	P:part	P	P	A	P:< ⅓
S045V0055	M	MA	P:trace	P	P	A	A
S488V1037	PF	MA	P:trace	A	A	A	A
S476V1054	PF	MA	A	A	A	A	P:< ⅓
S088V0094	F	LYA	A	P	P	A	A
S401V0876	F	LYA	P:com	P	A	A	A
S347V0741	M	OA	P:trace	P	A	A	A
S501V1097	F	EYA	A	A	P	A	A
S236V0335	M	EYA	P:trace	P	A	A	A
S495V1041	F	LYA	A	P	P	A	A
S487V1096	F	LYA	P:com	P	P	A	A
S126V0184	PF	MA	A	A	A	A	A
S285V0452	M	OA	P:trace	P	P	A	A
S306V0561	M	LYA	P:trace	A	P	A	A
S151V0666	F	LYA	A	A	A	A	P:< ⅓
S331V0735	F	OA	P:trace	P	P	A	A
S468V1009	F	MA	A	P	P	A	P:> ⅓
S360V0762	F	OA	A	A	A	P:< ⅓	P: <⅓
S281V0542	PM	MA	U	U	U	U	U
S388V0952	F	EYA	P:trace	P	A	P:< ⅓	A
S261V0422	M	OA	P:trace	A	A	A	A

Skeleton #	Bregmatic Oss.	Parietal For.	H. Nuchal Line	Dble Condylar Fac.		Palatine Tor.
				L.	*R.*	
S427V0938	A	A	P:trace	A	A	A
S149V0280	A	P:left	A	A	A	P:trace
S290V0472	A	A	P:trace	A	A	A
S358V0763	A	P:right	A	A	A	P:trace
S525V1119	A	A	P:trace	A	A	U
S473V1003	A	A	P:trace	A	A	P:part
S064V0050	A	A	A	U	U	A
S045V0055	A	P:bilat	A	U	U	U
S488V1037	A	A	P:medium	A	A	A
S476V1054	A	A	A	P	P	A
S088V0094	A	P:right	A	U	U	P:part
S401V0876	A	A	A	A	A	A
S347V0741	A	A	A	A	A	P:trace
S501V1097	U	P:right	A	A	A	A
S236V0335	A	P:right	A	A	A	P:trace
S495V1041	A	A	A	A	A	U
S487V1096	A	A	A	A	A	U
S126V0184	A	P:bilat	A	U	U	U
S285V0452	A	P:right	A	P	P	A
S306V0561	A	A	A	P	A	A
S151V0666	A	A	A	A	A	A
S331V0735	A	A	P:trace	U	U	U
S468V1009	A	A	A	A	A	A
S360V0762	A	A	P:trace	A	A	U
S281V0542	U	U	U	U	U	U
S388V0952	A	P:right	A	A	A	A
S261V0422	A	P:left	A	A	A	P:part

Skeleton #	Mylohyoid Br.		Mental Sp.	Double Atlas Facet		Sacralisation	Sternal For.
	L.	*R.*		*L.*	*R.*		
S427V0938	A	A	A	A	A	A	A
S149V0280	A	A	P:<2mm	A	A	A	A
S290V0472	P:com	P:com	P:<2mm	P:sep	P:sep	A	A
S358V0763	A	A	P:<2mm	P:sep	P:sep	A	U
S525V1119	A	A	P:<2mm	A	A	A	U
S473V1003	A	A	P:<2mm	A	A	A	A
S064V0050	A	A	A	P:sep	P:sep	A	U
S045V0055	A	A	A	U	U	A	A
S488V1037	A	A	P:<2mm	P:join	P:sep	A	A
S476V1054	P:com	A	P:<2mm	P:sep	P:sep	A	A
S088V0094	A	A	A	P:sep	P:sep	A	A
S401V0876	P:com	A	A	A	A	A	A
S347V0741	A	A	P:<2mm	A	A	A	A
S501V1097	A	P:com	P:<2mm	A	P:sep	A	A
S236V0335	A	A	P:<2mm	P:sep	A	P:L5-S1	U
S495V1041	P:com	P:com	A	A	A	A	U
S487V1096	A	P:com	P:<2mm	A	A	A	U
S126V0184	U	U	U	U	U	A	U
S285V0452	A	P:part	A	P:sep	P:sep	A	A
S306V0561	A	A	A	P:sep	A	A	U
S151V0666	A	A	A	A	A	A	A
S331V0735	A	A	A	U	U	A	A
S468V1009	P:com	A	A	U	U	P:L5-S1	A
S360V0762	U	U	A	A	A	A	A
S281V0542	A	A	A	U	U	A	A
S388V0952	A	P:part	P:<2mm	A	P:sep	P:L6-S1	A
S261V0422	A	A	P:<2mm	A	A	A	U

Skeleton #	Os Acrom.		Supracond. Proc.		Septal Aperture		Trochlear Spur	
	L.	*R.*	*L.*	*R.*	*L.*	*R.*	*L.*	*R.*
S427V0938	A	A	A	A	A	A	A	A
S149V0280	A	A	A	A	P:perf	P:perf	P:part	A
S290V0472	A	A	A	A	A	A	P:part	P:part
S358V0763	A	U	A	A	A	A	P:part	P:com
S525V1119	A	U	A	A	A	A	P:part	P:part
S473V1003	A	A	A	A	A	A	A	A
S064V0050	U	U	A	A	A	A	A	P:part
S045V0055	A	A	A	A	A	A	A	A
S488V1037	A	A	A	A	A	A	P:com	P:com
S476V1054	A	A	A	A	A	A	P:part	A
S088V0094	P	P	A	A	A	A	A	A
S401V0876	A	P	A	A	A	A	A	A
S347V0741	A	A	A	A	A	A	A	A
S501V1097	A	A	A	A	A	A	A	A
S236V0335	A	A	A	A	A	A	A	A
S495V1041	U	U	A	U	A	U	P:part	U
S487V1096	A	A	A	A	A	A	U	P:part
S126V0184	U	U	A	A	A	A	A	U
S285V0452	A	A	A	A	A	A	A	A
S306V0561	A	A	A	A	A	A	A	A
S151V0666	U	U	A	A	A	A	P:part	P:part
S331V0735	A	A	A	A	A	A	A	U
S468V1009	A	A	A	A	A	A	A	A
S360V0762	P	A	A	A	A	A	P:part	A
S281V0542	A	U	A	U	A	U	A	A
S388V0952	A	A	A	A	A	A	A	A
S261V0422	U	A	U	A	U	A	U	P:com

Skeleton #	3rd Trochanter		Poirier's Fac.		Supernumerary Rib	Acetabular Cr.		Vastus N.	
	L.	*R.*	*L.*	*R.*		*L.*	*R.*	*L.*	*R.*
S427V0938	A	A	A	A	A	A	A	U	U
S149V0280	P	P	A	A	A	A	A	A	A
S290V0472	A	P	A	A	A	A	A	A	A
S358V0763	A	A	U	U	A	A	A	A	A
S525V1119	P	A	A	P	A	A	A	U	U
S473V1003	A	A	A	A	P: 1L thor rib	A	A	A	A
S064V0050	A	A	A	A	U	A	A	P	U
S045V0055	P	P	P	P	A	A	A	A	A
S488V1037	A	A	U	P	A	A	A	A	A
S476V1054	A	A	A	A	A	A	A	A	A
S088V0094	A	A	A	U	A	A	A	A	A
S401V0876	A	A	A	A	A	A	A	U	U
S347V0741	A	P	A	A	A	A	A	A	A
S501V1097	A	A	A	A	A	A	A	A	A
S236V0335	A	A	P	P	P: 1L cerv rib	A	A	A	A
S495V1041	A	A	U	U	A	A	U	U	U
S487V1096	P	P	A	U	A	A	A	A	A
S126V0184	U	A	U	U	A	A	A	U	U
S285V0452	P	P	U	U	A	A	A	A	A
S306V0561	P	A	A	A	A	A	A	A	A
S151V0666	A	A	A	A	A	A	A	A	A
S331V0735	A	A	A	A	A	A	A	P	A
S468V1009	A	A	A	A	A	A	A	A	A
S360V0762	A	A	A	A	A	A	A	A	A
S281V0542	A	A	A	U	A	A	A	A	U
S388V0952	A	A	A	A	A	A	A	U	U
S261V0422	A	U	A	U	U	A	A	A	A

Skeleton #	Tibial Squatting Fac.		Talar Squatting Fac.		Double Calcaneal Facet	
	L.	*R.*	*L.*	*R.*	*L.*	*R.*
S427V0938	P:medium	P:medium	A	A	P	P
S149V0280	A	A	A	A	A	A
S290V0472	P:medium	A	A	A	P	P
S358V0763	A	P:medium	U	A	U	A
S525V1119	A	A	A	A	U	A
S473V1003	A	A	P	P	P	A
S064V0050	P:small	P:small	A	U	P	P
S045V0055	P:medium	P:medium	A	P	P	P
S488V1037	P:small	A	P	P	P	P
S476V1054	P:medium	P:medium	P	P	A	A
S088V0094	P:medium	P:medium	A	A	A	A
S401V0876	A	A	P	A	P	A
S347V0741	A	A	P	P	P	A
S501V1097	A	A	P	U	P	U
S236V0335	A	A	P	P	P	P
S495V1041	U	U	U	U	U	U
S487V1096	A	A	A	A	A	A
S126V0184	U	A	A	A	P	P
S285V0452	A	A	A	A	A	A
S306V0561	A	A	A	A	A	A
S151V0666	A	P:medium	A	A	A	A
S331V0735	A	A	P	A	U	P
S468V1009	A	A	U	A	P	P
S360V0762	P:medium	U	A	A	P	P
S281V0542	P:small	P:small	A	P	P	P
S388V0952	A	A	A	P	P	P
S261V0422	A	A	A	A	P	P

Skeleton #	Sex	Age	Metopic Sut.	Supraorb. Foramen	
				L.	*R.*
S379V0851	M	EYA	P:trace	A	A
S390V0831	F	MA/OA	P:trace	P	P
S340V0724	PM	<39	A	A	A
S345V0757	F	EYA	A	P	P
S498V1071	F	MA	A	A	A
S257V1006	M	OA	P:trace	A	A
S158V0472	M	LYA	P:trace	A	A
S430V0965	F	OA	P:com	P	P
S467V1022	M	LYA	P:trace	P	P
S121V0211	PF	LYA	A	A	A
S233V0304	M	MA	P:trace	P	P
S435V0929	M	MA/OA	P:trace	A	A
S053V0290	F	MA	P:trace	P	A
S250V0402	M	MA	P:trace	P	P
S402V0907	M	OA	P:trace	A	A
S453V0973	F	MA	P:com	A	P
S369V0886	F	LYA	A	P	P
S337V0714	M	LYA	P:trace	P	P
S216V0233	F	OA	A	P	P
S504V1109	F	MA	A	P	A
S070V0067	M	MA	A	A	P
S397V0842	PF	MA/OA	P:trace	A	A
S497V1059	M	OA	A	P	A
S502V1062	M	LYA	A	P	P
S404V1134	M	EYA	P:trace	A	A
S059V0133	M	LYA	P:trace	A	A
S356V0864	PF	MA	U	P	U
S521V1150	PM	MA	A	A	P
S374V0861	M	MA	P:trace	A	A
S432V0981	M	OA	A	P	A
S092V0124	M	LYA	A	A	A

Skeleton #	Mastoid Foramen		Bregmatic Oss.	Parietal Foramen
	L.	*R.*		
S379V0851	P:1@temp.	U	A	A
S390V0831	A	A	A	A
S340V0724	A	P: 1@temp.	A	A
S345V0757	P:1@temp.	P: 1@temp.	A	P:bilat
S498V1071	P:1@temp.	P: 1@temp.	A	A
S257V1006	P:1@occip.	P: 1@occip.	A	A
S158V0472	P: 1@occip.mast.	P: 1@occip.mast.	A	P:right
S430V0965	A	A	A	A
S467V1022	P: 2@temp.	P:1@temp.	A	A
S121V0211	P: 1@occip.mast	A	A	P:right
S233V0304	P: 1@temp.	P:1@temp.	A	A
S435V0929	A	U	A	P:left
S053V0290	A	U	A	A
S250V0402	P: 1@temp.	P:1@temp.	A	A
S402V0907	P: 1@temp.	P:2@occip., 1@temp.	A	P:right
S453V0973	P: 1@occip.mast.	P:1@occip.mast.	A	P:bilat
S369V0886	A	A	A	A
S337V0714	P: 1@occip.mast., 2@temp.	P:1@temp.	A	A
S216V0233	A	P:1@temp.	A	A
S504V1109	P: 1@temp.	P:1@temp.	A	P:bilat
S070V0067	A	A	A	A
S397V0842	P: 1@occip.	P:1@temp.	A	A
S497V1059	P: 1@temp.	P:1@temp.	A	P:right
S502V1062	P: 1@temp.	P:2@temp.	A	P:left
S404V1134	A	P:1@temp.	A	P:left
S059V0133	P: 1@temp.	P:1@occip.mast	A	A
S356V0864	P: 2@temp.	P:1@occip.	A	P:left
S521V1150	P: 1@occip.mast.	U	A	A
S374V0861	P: 1@occip.mast., 1@temp.	P:1@occip.mast,2@temp.	A	P:left
S432V0981	P: 1@occip.mast., 1@temp.	P:1@temp.	A	A
S092V0124	P: 1@occip.mast., 1@temp.	P 1@temp.	A	A

Skeleton #	H. Nuchal Line	Double Condylar Fac.		Palatine Torus	Mylohyoid Bridge	
		L.	*R.*		*L.*	*R.*
S379V0851	U	A	A	U	A	A
S390V0831	P:trace	U	U	U	A	A
S340V0724	A	A	A	P:trace	A	A
S345V0757	P:trace	P	P	A	A	A
S498V1071	A	A	A	A	P:part	P:part
S257V1006	P:trace	P	P	A	P:trace	P:trace
S158V0472	P:medium	A	A	P:trace	P:com	P:com
S430V0965	U	A	A	A	A	A
S467V1022	P:medium	A	A	A	P:com	P:com
S121V0211	A	A	A	U	U	U
S233V0304	A	A	A	A	A	A
S435V0929	U	A	A	P:trace	A	A
S053V0290	U	A	A	P:trace	A	A
S250V0402	P:trace	U	U	U	U	U
S402V0907	A	A	A	P:trace	A	A
S453V0973	A	A	A	A	P:part	P:com
S369V0886	A	A	A	A	P:part	P:com
S337V0714	P:medium	P	P	P:part	A	A
S216V0233	A	A	A	P:trace	P:trace	P:com
S504V1109	P:trace	A	A	P:trace	A	P:trace
S070V0067	P:medium	A	A	A	A	A
S397V0842	A	A	A	P:trace	A	A
S497V1059	A	A	A	P:trace	A	P:part
S502V1062	A	A	A	A	A	A
S404V1134	P:trace	A	A	A	P:com	P:com
S059V0133	A	A	A	P:trace	A	A
S356V0864	U	U	U	A	P:trace	A
S521V1150	P:trace	A	A	U	U	A
S374V0861	P:medium	A	A	A	A	P:trace
S432V0981	A	A	A	A	P:com	P:com
S092V0124	A			A	A	A

Skeleton #	Mental Spine	Double Atlas Facet		Sacralisation	Sternal Foramen	Os Acrom.	
		L.	*R.*			*L.*	*R.*
S379V0851	P:<2mm	P:join	P:join	P:L5-S1	A	A	A
S390V0831	P:<2mm	A	A	A	A	A	A
S340V0724	P:<2mm	P:join	P:join	A	A	U	U
S345V0757	A	P:join	P:join	P:L6-S1	A	A	A
S498V1071	P:<2mm	A	A	A	A	A	A
S257V1006	P:<2mm	P:join	P:join	P L6-S1	A	P	P
S158V0472	A	P:join	P:join	P:L6-S1	A	A	A
S430V0965	A	P:sep	P:sep	A	A	P	P
S467V1022	P:<2mm	P:sep	P:join	A	P:perf	A	A
S121V0211	U	U	U	U	U	U	U
S233V0304	P:<2mm	U	U	P:right side	U	A	A
S435V0929	P:<2mm	P:sep	P:join	P:L5-S1	A	A	A
S053V0290	P:<2mm	U	U	A	U	U	U
S250V0402	U	U	U	A	U	U	U
S402V0907	P:<2mm	A	P:join	A	A	A	A
S453V0973	P:<2mm	A	A	A	A	A	A
S369V0886	P:<2mm	A	A	A	A	A	A
S337V0714	P:<2mm	P:sep	P:sep	P:L5-S1	U	A	A
S216V0233	A	A	A	P:L5-S1	P:perf	A	A
S504V1109	A	A	A	A	A	P	A
S070V0067	A	P:sep	P:sep	A	U	U	U
S397V0842	A	P:join	P:join	A	A	A	A
S497V1059	P:<2mm	P:join	P:join	A	U	A	A
S502V1062	P:<2mm	P:join	P:join	A	A	A	A
S404V1134	A	A	A	A	A	A	A
S059V0133	P:<2mm	P:join	P:join	A	A	A	A
S356V0864	A	A	A	P:left side	U	A	A
S521V1150	P:<2mm	A	A	A	A	A	A
S374V0861	A	A	A	A	A	A	A
S432V0981	A	U	U	A	A	A	A
S092V0124	P:<2mm	P:join	P:join	A	U	A	A

Skeleton #	Supracond. Process		Septal Aperture		Trochlear Spur		3rd Trochanter		Poirier's Fac.	
	L.	*R.*	*L.*	*R.*	*L.*	*R.*	*L.*	*R.*	*L.*	*R.*
S379V0851	A	A	A	P:perf	A	A	A	A	A	A
S390V0831	A	A	A	A	A	A	A	A	U	U
S340V0724	A	A	A	A	A	A	A	P	A	P
S345V0757	A	A	A	A	A	A	A	A	A	A
S498V1071	A	A	A	A	A	A	P	P	A	A
S257V1006	A	A	A	A	P:part	P:part	A	A	A	A
S158V0472	A	A	A	A	P:com	P:part	P	A	A	A
S430V0965	A	A	A	A	P:part	P:part	A	A	A	A
S467V1022	A	A	A	A	P:part	P:part	A	A	P	P
S121V0211	U	U	U	U	U	U	U	U	U	U
S233V0304	A	A	A	A	A	P:part	A	A	A	A
S435V0929	A	A	A	A	P:part	P:part	A	A	A	A
S053V0290	A	A	A	A	P:part	A	A	A	A	A
S250V0402	A	A	U	U	U	U	U	P	U	U
S402V0907	A	A	A	A	P:part	P:part	A	A	P	P
S453V0973	A	A	A	A	P:part	P:part	A	A	A	A
S369V0886	A	A	A	A	A	A	A	A	A	A
S337V0714	A	A	A	A	P:com	P:comp	A	A	P	P
S216V0233	A	A	A	A	P:part	A	A	P	A	A
S504V1109	A	A	A	A	P:part	A	A	A	A	A
S070V0067	U	U	U	U	U	U	A	A	A	A
S397V0842	A	A	A	A	U	P:com	A	A	U	U
S497V1059	A	A	A	A	P:part	P:com	A	A	P	P
S502V1062	A	A	A	A	P:part	A	A	A	A	A
S404V1134	A	U	A	U	P:part	U	A	A	A	A
S059V0133	A	A	A	A	P:part	P:part	A	A	A	A
S356V0864	A	A	A	A	P:part	A	A	A	A	A
S521V1150	A	A	A	A	P:part	P:com	A	A	P	P
S374V0861	A	A	A	A	P:part	P:com	U	A	U	A
S432V0981	A	A	A	A	P:part	P:part	A	A	A	A
S092V0124	A	A	A	A	A	A	A	A	A	A

Skeleton #	Supernumerary Rib	Acetabular Crease		Vastus Notch		Tibial Squatting Fac.	
		L.	*R.*	*L.*	*R.*	*L.*	*R.*
S379V0851	A	A	A	A	A	P:medium	P:medium
S390V0831	A	U	A	U	A	U	U
S340V0724	A	A	A	U	A	A	A
S345V0757	A	A	A	U	U	P:medium	P:medium
S498V1071	A	A	A	A	U	A	A
S257V1006	A	A	A	U	A	P:medium	P:medium
S158V0472	A	A	A	U	U		
S430V0965	A	A	A	U	A	A	P:medium
S467V1022	A	A	A	U	U	P:small	P:small
S121V0211	U	U	U	U	A	A	A
S233V0304	A	A	A	U	U	U	P:small
S435V0929	A	A	A	A	A	P:small	P:small
S053V0290	A	A	A	A	A	P:small	P:small
S250V0402	A	A	A	A	A	P:small	P:small
S402V0907	A	A	A	A	A	A	A
S453V0973	A	A	A	U	A	P:small	P:small
S369V0886	A	A	A	A	A	A	P:small
S337V0714	A	A	A	A	U	A	A
S216V0233	A	A	A	A	A		
S504V1109	A	A	A	A	A	P:medium	P:medium
S070V0067	U	A	A	A	A	A	A
S397V0842	A	A	A	A	A	U	U
S497V1059	A	A	A	A	A	A	A
S502V1062	A	A	A	A	A	P:medium	P:medium
S404V1134	A	A	A	A	A	A	P:medium
S059V0133	A	A	A	U	A	P:small	P:small
S356V0864	A	A	A	A	A	P:small	U
S521V1150	P:1R thor ribhead	A	A	A	A	A	A
S374V0861	A	A	U	A	A	A	P:small
S432V0981	A	A	U	A	A	P:small	P:small
S092V0124	A	A	A	U	A	P:small	P:medium

Skeleton#	Talar Squatting Fac.		Double Calcaneal Facet	
	L.	*R.*	*L.*	*R.*
S379V0851	A	A	P	P
S390V0831	A	P	P	P
S340V0724	A	A	P	P
S345V0757	A	A	A	A
S498V1071	A	A	P	P
S257V1006	U	U	U	U
S158V0472	A	A	P	P
S430V0965	A	A	A	A
S467V1022	A	A	P	P
S121V0211	U	U	U	U
S233V0304	A	A	P	P
S435V0929	A	A	A	A
S053V0290	A	A	P	P
S250V0402	A	U	A	U
S402V0907	P	A	P	P
S453V0973	A	A	P	P
S369V0886	U	P	U	P
S337V0714	P	P	P	P
S216V0233	A	A	A	A
S504V1109	A	A	P	P
S070V0067	A	A	A	A
S397V0842	A	P	P	P
S497V1059	A	A	A	A
S502V1062	A	A	P	P
S404V1134	A	U	A	U
S059V0133	A	A	P	P
S356V0864	A	A	A	A
S521V1150	U	U	P	A
S374V0861	P	P	U	P
S432V0981	A	A	U	U
S092V0124	A	A	A	A

Skeleton #	Sex	Age	Metopic Sut.	Supraorbital For.		Auditory Exo.	
				L.	*R.*	*L.*	*R.*
S310V0550	M	LYA	P:trace	A	A	A	A
S482V1048	M	MA	P:trace	A	P	A	A
S368V0794	M	LYA	P:trace	A	P	A	A
S413V0896	F	MA	A	A	A	A	A
S405V0882	M	MA	P:trace	P	P	A	A
S317V0649	M	OA	U	A	P	A	A
S466V1010	F	MA	A	P	P	P:<⅓	A
S243V0381	F	MA	A	P	P	A	P:< ⅓
S385V0874	F	EYA	A	A	A	A	A
S239V0369	M	EYA	P:com	A	P	A	A
S238V0350	M	EYA	U	P	U	A	A
S198V0601	F	LYA	A	P	P	A	A
S370V0806	F	LYA	A	P	P	P:< ⅓	A
S313V0926	M	MA	P:com	A	P	A	A
S294V0487	F	OA	P:trace	A	P	A	A
S270V1067	M	EYA	P:trace	A	A	A	A
S183V0311	F	LYA	A	A	P	A	A
S512V1105	F	MA	P:trace	P	P	A	P:< ⅓
S527V1153	F	LYA	A	A	A	A	A
S339V0728	F	MA/OA	A	P	A	A	P:spicule
S263V0445	M	>40	P:part	P	P	A	A
S524V1120	M	MA	P:trace	P	A	A	A
S461V0990	PF	MA	A	A	P	P:< ⅓	A
S505V1095	PM	EYA	A	A	A	A	A
		EYA					

Skeleton #	Mastoid Foramen		Bregmatic Oss.	Parietal For.	H. Nuchal Line
	L.	*R.*			
S310V0550	P:1@occip.mast., 1@temp.	P:1@occip.mast.	A	A	A
S482V1048	A	P:1@occip.mast., 1@temp.	A	P:right	A
S368V0794	P:1@temp.	P:1@temp.	A	P:left	P:trace
S413V0896	U	U	A	P:left	A
S405V0882	A	A	A	P:right	A
S317V0649	A	A	A	A	P:trace
S466V1010	P:1@temp.	P:1@temp.	A	P:left	A
S243V0381	P:1@occip.mast.	P:1@occip.mast., 2@temp.	A	P:bilat.	P:trace
S385V0874	A	A	A	A	A
S239V0369	A	P:1@temp.	A	A	A
S238V0350	P:1@occip.mast.	P:1@temp.	U	U	U
S198V0601	P:1@occip.mast., 1@temp.	P:1@occip.mast., 1@temp.	A	P:left	P:trace
S370V0806	A	A	A	P:right	A
S313V0926	P:1@temp.	A	A	P:bilat.	A
S294V0487	P:1@temp.	P:1@temp.	A	P:right	P:medium
S270V1067	P:1@temp.	A	U	U	U
S183V0311	P:2@temp.	P:1@occip.mast., 1@temp.	A	A	P:medium
S512V1105	A	A	A	P:left	A
S527V1153	P:1@temp.	P:1@temp.	A	A	P:trace
S339V0728	U	P:2@occip.mast., 1@temp.	A	A	P:trace
S263V0445	P:2@occip.	P:1@occip.mast.	A	A	P:medium
S524V1120	P:1@occip.mast.	A	A	A	P:medium
S461V0990	P:1@occip.mast.	U	A	A	P:trace
S505V1095	P:1@occip.	A	A	A	A

Skeleton #	Double Condylar Fac.		Palatine Torus	Mylohyoid Bridge		Mental Spine	Double Atlas Facet	
	L.	*R.*		*L.*	*R.*		*L.*	*R.*
S310V0550	A	A	P:part	P:part	P:com	P:<2mm	A	A
S482V1048	P	P	A	A	A	P:<2mm	P:sep	P:sep
S368V0794	A	P	P:com	P:com	P:trace	P:<2mm	P:join	P:sep
S413V0896	A	A	P:trace	P:trace	A	P:<2mm	A	A
S405V0882	A	A	A	A	A	A	P:join	P:join
S317V0649	U	U	U	A	A	P:<2mm	U	U
S466V1010	A	A	P:trace	U	A	A	P:join	P:join
S243V0381	A	A	A	P:trace	P:part	A	P:join	P:join
S385V0874	U	A	A	A	P:com	A	P:join	U
S239V0369	A	U	A	A	A	P:<2mm	A	A
S238V0350	A	A	P:trace	A	A	P:<2mm	A	A
S198V0601	A	A	A	P:trace	A	A	P:sep	P:join
S370V0806	A	A	A	A	P:com	A	P:join	P:sep
S313V0926	A	A	P:part	A	A	A	P:join	P:join
S294V0487	A	A	P:part	P:part	A	P:>2mm	A	A
S270V1067	U	A	U	P:part	A	P:<2mm	P:join	P:join
S183V0311	A	U	P:part	U	A	P:<2mm	P:join	P:join
S512V1105	P	P	P:part	P:part	P:part	A	P:join	P:sep
S527V1153	A	A	A	P:part	P:part	P:<2mm	P:join	P:join
S339V0728	U	A	A	A	A	P:<2mm	U	U
S263V0445	U	A	P:trace	A	U	A	U	A
S524V1120	P	P	P:part	P:trace	A	A	P:sep	P:sep
S461V0990	P	A	A	P:part	A	P:<2mm	P:join	P:sep
S505V1095	A	A	P:trace	A	P:trace	P:<2mm	P:join	P:join
				P:trace	A			

Skeleton #	Sacralisation	Sternal Foramen	Os Acrom.		Supracondylar Proc.		Septal Aperture	
			L.	*R.*	*L.*	*R.*	*L.*	*R.*
S310V0550	A	U	U	U	A	A	A	A
S482V1048	A	A	P	A	A	A	A	A
S368V0794	A	U	U	A	A	U	A	U
S413V0896	A	U	A	P	A	U	A	U
S405V0882	A	A	A	A	A	A	A	A
S317V0649	A	U	U	A	A	A	A	A
S466V1010	U	A	U	U	A	A	P:perf	P:perf
S243V0381	U	A	U	A	A	A	A	A
S385V0874	A	U	U	U	U	U	U	U
S239V0369	A	A	A	A	A	A	A	A
S238V0350	A	U	A	A	A	A	A	A
S198V0601	A	U	U	U	A	A	A	A
S370V0806	A	A	A	A	A	A	P:perf	A
S313V0926	A	A	U	A	A	A	A	A
S294V0487	A	A	A	U	A	A	A	A
S270V1067	A	A	A	A	A	A	A	A
S183V0311	A	A	A	A	A	A	A	A
S512V1105	A	A	U	U	A	A	A	A
S527V1153	A	A	A	A	A	A	P:perf	A
S339V0728	A	U	U	U	A	A	A	A
S263V0445	A	A	A	A	A	A	A	A
S524V1120	A	U	A	A	A	A	A	A
S461V0990	A	U	U	U	A	A	P:perf	P:perf
S505V1095	A	A	A	A	A	A	A	A

Skeleton #	Trochlear Spur		3rd Trochanter		Poirier's Fac.		Supernumerary Rib	Acetabular Crease	
	L.	*R.*	*L.*	*R.*	*L.*	*R.*		*L.*	*R.*
S310V0550	P:part	P:part	A	A	A	A	A	A	A
S482V1048	P:part	P:part	A	A	A	A	A	A	A
S368V0794	A	U	A	A	A	A	A	A	A
S413V0896	P:part	P:part	U	A	U	A	A	A	A
S405V0882	A	P:part	A	A	A	A	P:1L cerv. rib	A	A
S317V0649	P:com	P:part	A	A	A	A	A	A	A
S466V1010	P:com	A	A	A	A	A	A	A	A
S243V0381	P:part	A	A	A	A	A	A	A	U
S385V0874	U	U	A	A	A	A	U	A	A
S239V0369	A	A	P	P	A	A	A	A	A
S238V0350	P:part	P:part	U	U	U	U	A	A	A
S198V0601	P:part	P:part	A	A	A	A	A	A	A
S370V0806	A	P:part	A	P	A	A	A	A	A
S313V0926	P:part	P:part	A	A	A	A	A	A	A
S294V0487	A	P:part	A	A	P	A	P:1L, 1R cerv. rib	A	A
S270V1067	P:part	P:part	A	P	P	P	A	A	A
S183V0311	P:com	P:com	A	A	P	P	A	A	A
S512V1105	P:part	P:com	P	A	P	P	A	A	A
S527V1153	A	A	P	P	P	P	A	A	A
S339V0728	P:part	A	P	P	A	A	A	A	A
S263V0445	P:part	U	A	A	P	P	A	A	A
S524V1120	P:part	P:part	P	P	P	P	A	A	A
S461V0990	A	A	A	A	A	A	A	A	A
S505V1095	P:part	A	A	A	A	A	A	A	A

Skeleton #	Vastus Notch		Tibial Squatting Fac.		Talar Squatting Fac.		Double Calcaneal Facet	
	L.	*R.*	*L.*	*R.*	*L.*	*R.*	*L.*	*R.*
S310V0550	A	A	P:medium	P:medium	A	A	P	P
S482V1048	U	A	P:small	A	A	A	P	P
S368V0794	U	U	P:small	P:small	A	A	P	P
S413V0896	A	A	P:small	P:small	A	A	A	A
S405V0882	U	U	P:medium	P:medium	U	U	U	A
S317V0649	A	A	U	P:small	A	A	A	P
S466V1010	U	U	P:small	P:small	A	A	U	P
S243V0381	A	U	P:small	U	A	P	P	P
S385V0874	U	U	P:small	P:small	A	A	P	P
S239V0369	A	A	P:small	P:small	A	A	A	A
S238V0350	A	U	U	U	U	U	U	U
S198V0601	U	A	P:medium	A	A	A	A	A
S370V0806	A	A	P:small	A	A	A	A	A
S313V0926	A	U	A	A	A	A	P	P
S294V0487	A	A	A	P:small	P	A	A	A
S270V1067	A	A	A	A	A	A	A	A
S183V0311	A	A	P:medium	P:medium	A	A	P	P
S512V1105	A	A	P:small	P:small	A	A	A	U
S527V1153	A	A	P:medium	P:small	A	A	P	P
S339V0728	A	U	U	U	A	A	P	P
S263V0445	A	U	P:small	P:small	A	U	A	A
S524V1120	A	A	A	A	A	A	P	P
S461V0990	A	A	P:small	A	P	P	A	A
S505V1095	U	U	U	U	U	U	U	U

Skeleton #	Sex	Age	Metopic Suture	Supraorbital For.		Auditory Exo.	
				L.	*R.*	*L.*	*R.*
S481V1046	F	LYA	A	A	A	A	A
S307V0591	F	EYA	A	P	A	P:spicule	P:< ⅓
S309V0616	F	MA	A	A	A	A	A
S174V0408	PF	MA	A	P	A	A	A
S387V0914	PF	MA/OA	A	A	P	A	A
S434V0958	F	>40	A	A	P	A	A
S344V0730	F	MA	P:trace	P	P	P:spicule	P:< ⅓
S253V0466	M	EYA	P:trace	P	P	A	P:< ⅓
S060V0037	F	OA	A	P	P	A	A
S278V0584	F	EYA	A	P	A	U	P: <⅓
S226V0282	M	MA LYA	P:trace	P	P	A	A

Skeleton #	Mastoid Foramen		Bregmatic Oss.	Parietal For.	H. Nuchal Line
	L.	*R.*			
S481V1046	P:2@temp.	P:2@temp.	A	P:bilat	P:trace
S307V0591	A	A	A	A	A
S309V0616	P:1@occip.mast.	P:1@temp.	A	P:right	A
S174V0408	A	A	A	A	A
S387V0914	P:1@occip.	P:1@occip.	A	P:right	P:medium
S434V0958	A	P:2@occip., 1@temp.	A	A	A
S344V0730	P:1@occip.	P:1@occip.	A	P:right	P:strong
S253V0466	P:1@occip.	P:1@occip.	U	P:right	P:strong
S060V0037	A	P:1@temp.	A	P:left	A
S278V0584	U	A	A	U	A
S226V0282	A	A	A	P:right	P:medium

Skeleton #	Double Condylar Fac.		Palatine Torus	Mylohyoid Br.		Mental Spine	Double Atlas Facet	
	L.	*R.*		*L.*	*R.*		*L.*	*R.*
S481V1046	P	P	A	U	U	U	P:sep	P:sep
S307V0591	A	A	A	A	A	A	A	A
S309V0616	A	P	A	A	A	P:<2mm	P:sep	P:join
S174V0408	A	A	P:part	A	A	A	P:join	P:sep
S387V0914	A	A	P:trace	U	U	U	U	U
S434V0958	P	P	P:trace	U	U	U	P:sep	U
S344V0730	U	U	P:trace	A	P:com	P:<2mm	P:join	P:join
S253V0466	P	A	P:part	A	P:com	P:<2mm	P:join	P:sep
S060V0037	A	A	P:trace	P:part	P:part	P:<2mm	P:join	P:join
S278V0584	U	A	A	A	A	P:<2mm	P:join	P:join
S226V0282	P	P	A	A	A	A	P:sep	P:sep

Skeleton #	Sacralisation	Sternal Foramen	Os Acrom.		Supracondylar Proc.		Septal Aperture	
			L.	*R.*	*L.*	*R.*	*L.*	*R.*
S481V1046	A	U	U	A	A	A	A	A
S307V0591	P: L5-S1	A	A	A	A	A	A	A
S309V0616	A	U	P	P	A	A	A	A
S174V0408	A	U	A	A	A	A	A	A
S387V0914	U	U	U	U	U	U	U	U
S434V0958	A	A	U	A	U	A	U	A
S344V0730	A	A	A	A	A	A	A	A
S253V0466	P: L5-S1	U	A	A	A	A	P:perf	A
S060V0037	A	A	U	U	A	A	A	A
S278V0584	A	A	A	A	A	A	A	A
S226V0282	A	A	A	P	A	A	A	A

Skeleton #	Trochlear Spur		3rd Trochanter		Poirier's Fac.		Supernumerary Rib	Acetabular Crease	
	L.	*R.*	*L.*	*R.*	*L.*	*R.*		*L.*	*R.*
S481V1046	A	A	A	A	A	A	A	A	A
S307V0591	P:part	P:part	A	A	A	A	A	A	A
S309V0616	P:part	P:com	A	A	A	A	P:1 thor 13th rib	A	A
S174V0408	U	P:part	A	A	A	A	A	A	A
S387V0914	U	U	U	U	U	U	U	U	U
S434V0958	P:com	P:com	P	P	A	A	A	A	A
S344V0730	U	A	A	A	A	A	A	A	A
S253V0466	P:com	P:part	A	A	U	U	A	A	A
S060V0037	P:part	U	A	A	A	A	A	A	A
S278V0584	P:part	P:part	P	P	A	A	A	A	A
S226V0282	A	A	A	A	A	A	A	A	A

Skeleton #	Vastus Notch		Tibial Squatting Fac.		Talar Squatting Fac.		Double Calcaneal Facet	
	L.	*R.*	*L.*	*R.*	*L.*	*R.*	*L.*	*R.*
S481V1046	U	A	P:large	P:small	A	A	A	A
S307V0591	A	A	A	A	A	A	P	P
S309V0616	A	A	P:small	A	A	A	P	P
S174V0408	A	A	A	A	A	A	P	P
S387V0914	U	A	U	P:small	A	A	U	P
S434V0958	A	A	U	P:medium	A	P	P	P
S344V0730	U	U	P:medium	P:medium	P	P	A	P
S253V0466	U	U	P:small	P:small	A	A	A	A
S060V0037	A	U	P:small	U	A	A	A	A
S278V0584	U	A	A	A	A	A	P	P
S226V0282	A	A	A	A	A	A	P	P

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