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HUMAN REMAINS FROM THE CLOISTER GARTH OF THE 'KONINGSVELD' PRIORY NEAR THE MEDIAEVAL CITY OF DELFT, Ca. 1450-1572 AD

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SUMMARY

A physical anthropological study was performed on 37 of the 112 skeletons excavated within the alleys of the cloister garth (Dutch: *kloosterhof*) belonging to the '*Koningsveld*' Priory (1252-1572 AD). This priory was situated south of the Late Mediaeval city of Delft. The excavated cloister garth was dated between ca. 1450 and 1572 AD. The Municipal Archaeological Service of Delft was responsible for the excavation. The physical anthropological analysis was performed at the department of Anatomy of the Leiden University Medical Center. DNA analysis on eight of the excavated skeletons was performed at the Human Biological Trace Department of the Netherlands Forensic Institute.

About one third of the deceased studied in our sample were male, two third were female. The average age at death was 43.2 years. The average stature was 173.6 cm for males (Breitinger, 1937) and 161.8 cm for females (Trotter and Gleser, 1958). The post-mortem tooth loss was low (12.5%), which points to careful excavation and handling of the skeletons. According to the high ante-mortem tooth loss and caries frequency, tooth decay was a serious problem. Next to a number of common palaeopathologies, some interesting variants were observed and described.

In addition, some methodological and taphonomic biases regarding the analysis of skeletal material from archaeological contexts will be addressed.

INTRODUCTION

Historical introduction

In 1246 AD, count Willem II of Holland and Zeeland (ca. 1228-1256) granted city rights to a developing trading settlement along a channel named *Delf*. This charter was issued through mediation of Richardis (ca. 1210-1263), sister of count Floris IV (1210-1234) and parental aunt of Willem II. In mid 13th century, the number of inhabitants within the city of Delft was estimated at ca. 400-500. People outside the city were engaged in farming, while townspeople were processing and trading the agricultural products and probably acted as suppliers of agricultural services. In order to provide housing and space for the constantly increasing population and businesses, the area favoured with city rights increased in size four times, until Delft obtained its largest territory during the Late Mediaeval period in 1355. At the end of the 14th century Delft was inhabited by approximately 6500 people, contained numerous houses with brick foundations, had developed specialized crafts (such as cloth- and beer production) and controlled an interregional trading route (Niermeyer, 1944; Raue, 1982; Verhoeven, 1992; Verhoeven, 2002). During the 15th century, Delft became one of the largest and most important cities within the County of Holland next to the cities of Dordrecht and Haarlem. Its population doubled from around 6500 inhabitants at the beginning of the 15th century to about 12.000-13.500 inhabitants at the end (Ramaer, 1921; Verhoeven, 1992; Verhoeven, 2002). In 1510 a plague decimated the population to about 10.000 inhabitants (Kok, 1979a; Verhoeven, 1992). A fire raged within the city in 1536. In the summer of 1566, widespread Protestant iconoclasm (Dutch: *beeldenstorm*) took place within Delft (Kok, 1979a; Kok, 1979b). The County of Holland, alongside other Counties, started a revolt against the Kingdom of Spain in 1568. Delft joined the revolt in 1572 and confiscated all Roman Catholic possessions within its territories. All buildings outside the city walls were demolished by order of Willem I of Orange-Nassau who feared that they would be used by the advancing Spanish forces as strongholds.

The 'Koningsveld' priory was founded in 1251 AD, when Willem II, who was by then crowned as a rival Holy Roman King, granted his aunt Richardis permission to establish a *conventum religiosorum* south of Delft, between the *Schie* channel and the present-day *Rotterdamseweg* (Figure 1). The name of the *conventum* was *Campus Regis*, or in Dutch: *Koningsveld* (Eng. *King's Field*). A year later, on June 2nd 1252, the auxiliary Bishop of Utrecht ordained the altar and graveyard within this newly built complex (Raue, 1982; Kruisheer, 1986; Verhoeven, 2002). Several papal bulls and charters issued between 1252 and 1290 are used by historians to deduce that the *conventum* was inhabited by nuns (Lat. *sanctimoniales*)[1] who followed the Second Rule of St. Augustine as prescribed by the Rule of St. Norbert. The *conventum* was under authority of the abbot of the Mariënweerd Abbey at Beesd (i.e. it was a priory) (Verhoeven, 2002).

The Premonstratensian Order (Lat. *Canonici Regulares Praemonstratenses*) was founded by St. Norbert, Archbishop of Magdeburg (ca. 1084-1134) in the valley of Prémontré near Laon (Northern France) in 1121. The Order propagated an ascetic life style, including poverty and gospel preaching in groups, by virtue of the apostles' example. The 12th century was a golden age for the Premonstratensians. Four years after the foundation of the Order the Premonstratensians possessed sixteen monasteries. In the second quarter of the 12th century this total surpassed a number of 500 (Bond, 1993). From the 13th century onwards the Order

[1] It is also conceivable that the *Koningsveld* complex was originally inhabited by monks (and nuns), and became a priory solely inhabited by nuns only after 1258 (Oosterbaan, 1954).

loosened its strict regime and its focus shifted to priestly duties in parishes, management of infirmaries, as well as gathering of knowledge (van de Perre, 1998). Within The Low Countries, the Order was also co-responsible for the reclamation of its forests and for the cultivation of the wetlands.

The Koningsveld Priory was the second establishment of the Premonstratensian Order founded within the *Graafschap Holland* (Eng. *County of Holland*), and until ca. 1400 AD it was the only monastic institute in or nearby Delft.[2] At its peak the priory possessed lands and estates within Delft, Delfland and Pijnacker, churches at Pijnacker and Schiedam, infirmaries at Delft and Schiedam and a chapel within the '*Te Riviere*' stronghold at Schiedam (Obreen, 1935; Obreen, 1936; Verhoeven, 2002). The priory itself was a small sized nunnery, which probably accommodated a maximum of twenty nuns, due to its restricted financial ability. The prior was its spiritual leader and represented the nuns outside the walls of the priory. A prioress, elected by the nuns, was responsible for the domestic affairs. According to historical sources, most nuns came from noble families. They spent their time with prayer, meditation and contemplation. Lay brothers and sisters together with servants and maids were responsible for all manual work. Until circa 1450 the lay brothers and sisters were also responsible for the care supplied within the '*Oude -en Nieuwe Gasthuis*' (Eng. *Old and New Infirmary*) at Delft.

According to Premonstratensian burial customs the following groups could be buried within a Premonstratensian nunnery or monastery (Van de Perre, 1998): (1) members of the Premonstratensian Order, (2) people who (accidentally) came to die within the ward (Lat. *hospitium*), (3) elderly who had joined the Order, (4) members of a praying community associated with the Order (Lat. *fraternitas*) and (5) people who made it clear in their wills that they wished to be buried within the walls of the nunnery or monastery and had the means to support their wish. It is important to mention that individual Premonstratensian nunneries and monasteries had various additional rules and observances of their own (Burton 1994). This implies that there could be a significant variation in the burial rules and customs between the individual Premonstratensian nunneries and monasteries.

In addition, depending on the religious order, the specific location of the cloister garth in its function as a burial location was of varying significance in the Late Mediaeval nunneries and monasteries. Therefore, a cloister garth could have been used for the burial of religious and/or secular groups (Gilchrist and Sloane, 2005).

Archaeological introduction

Four archaeological campaigns were performed within the boundaries of the Koningsveld complex (Bult and van der Steen, 2001a; Bult and van der Steen 2001b; Bult and Groen 2004). A large granary was excavated in 1988. An enclosing moat and several other ditches were encountered and partially excavated during the two campaigns of 2001. Finally, in 2003 structures interpreted as chapel, cloister garth (Dutch: *kloosterhof*), kitchen, rafter and living quarters (and/or storage rooms) were excavated, together with a graveyard including seven tombs (Fig. 2a). The dating of the Koningsveld complex was based on: (1) brick dimensions, (2) brick bonds, (3) foundation depths, (4) methods of foundation, (5) associations between separate walls and (6) the architectural styles used during construction (Lempke, 2004). The

[2] The first establishment was in '*Berne aan de Maas*', near Heusden where a Premonstratensian Abbey was founded in 1134 AD (van Rij, 1987).

wall structures within the complex were dated between the second half of the 13th century and the first half of the 16th century AD.

Within the excavated part of the graveyard 182 primary and at least 29 secondary interments were located. The graveyard consisted of three separate burial grounds, namely: (1) within the nave of the chapel, (2) within the corridors of the cloister garth and (3) within an open area west of the chapel. The encountered burial rites corresponded with the Christian way of interment. All deceased were buried lying in a coffin, extended on their backs with their heads towards the west. Arms and hands were placed on the chest or lap, or lay extended along the body. Additional historical and archaeological evidence showed that burials in the Late Mediaeval period were highly differentiated in terms of religious and socio-economic background and status of the deceased (Harding, 1992; Daniell, 1996; Hadley, 2001; Gilchrist and Sloane, 2005). Applying this evidence to the precinct of the Koningsveld Priory, it is to be expected that individuals buried within the inner space of the chapel (i.e. crossing and transepts) and individuals buried within the cloister garth had an important religious background or a high secular status. Individuals buried within the nave of the chapel and individuals buried within the cemetery west of the chapel had probably a regular religious background or a moderate secular status (Groen, in prep.).

The cloister garth

The cloister garth was enclosed by kitchen and rafter walls in the north, by the wall of the living quarters or storage rooms in the west, and by the wall of the chapel in the south. A separate wall enclosed the eastern area. The dimensions of the bricks used within the walls and buttresses of the cloister garth measured between 30 x 15 x 8 cm (3600 cm^3) and 22 x 11 x 5/4.5 cm (1210/1089 cm^3). The smallest bricks dated the foundation of the garth within the second half of the 15th century AD.[3] The historically known demolition date of 1572 AD corresponded with the date of closure of the cloister garth.

Out of the 182 primary interments excavated during the campaign of 2003, 112 were located within one of the four corridors of the cloister garth (Fig. 2b). The north corridor contained 14 interments, the west corridor 30 interments. The south and east corridors contained 57 and 11 interments, respectively. All interments were discovered within one of the several burial rows excavated within the corridors. Furthermore, based on the positioning of the skeletons and the presence of some brick wall remnants, it was likely that all corridors had originally been roofed and tiled.

[3] Similar brick dimensions were found within the pillar foundations of the Old Church at Delft (22 x 10.5 x 4.5 cm) where they were dated between 1425 and 1440 AD (Berends and Meischke, 1979) and within building 1 of the IHE complex (International Institute for Infrastructural, Hydraulic and Environmental Engineering) at Delft (22/21 x 11/10 x 4.5/4 cm) where they were dated in the second half of the 15th century AD (Bult, 1992).

MATERIAL and METHODS

A standardized physical anthropological report (Maat, 2004) was completed after articulation and reconstruction of the bones of each skeleton. This report included the determination of the completeness of the cranial and post-cranial skeleton, dental status, morphological sex determination, skeletal age determination, calculation of the living standing stature and a description of the anomalies and palaeopathologies. In addition, DNA research was performed on a subset of the skeletons to determine the sex by means of the amelogenin gene.

Material

From the 112 primary interments excavated within the corridors of the cloister garth, 84 skeletons (i.e. 75%) were (almost) complete. From these, a random sample of 37 (N = 37)[4] was collected and studied (i.e. 33% of the total garth population) as shown in Figure 2c. Eight interments were sampled from the north corridor (89%), fifteen from the west corridor (52%), thirteen from the south corridor (34%) and eight from the east corridor (100%). Seven interments were positioned on the crossing of two corridors and were counted in both of them. It is assumed that this sample represented the population buried within the garth.

Sex determination

Physical anthropological sex determination is only possible in adults. To assess the morphological sex development ten pelvic, eleven cranial and four mandibular traits were examined (WEA, 1980). Each trait had its own weight-factor and was scored from hyper-feminine (-2) via indifferent (0) to hyper-masculine (+2). The so-called 'degree of sexualisation' was calculated from the summed scores divided through the summed weight-factors. An alternative method to determine the sex uses the interval of the antero-posterior diameter (APD) and the maximum diameter of femora and tibiae (femur-APD, femur-max, tibia-APD and tibia-max, respectively), measured with a sliding calliper (MacLaughlin, 1985). To determine the common interval of overlap for both sexes, these values need to be collected for the total population under study, before diagnosing the sex for a specific individual. The diagnosis of a complete pelvis overruled all other morphological and metric sex determinations.

For a subset of eight skeletons the sex was also determined by DNA research. All procedures were performed in an ISO-17025 accredited laboratory, wearing protective clothing. A wedge was excised from the femur shaft (Westen et al., 2008), cleaned and grinded to bone powder with a nitrogen-cooled freezer mill (Spex). DNA was extracted with the QIAamp DNA Mini Kit (Qiagen) according to the manufacturer's protocol. The DNA concentration was measured with the Human Quantifiler kit (Applied Biosystems, AB) on an ABI 7900 real-time PCR (AB). One ng DNA was used as input for the AmpF*l*STR® SGM Plus® PCR (AB), which was performed in an ABI 9700 (AB). One of the DNA markers in the SGM Plus® kit aims at a part of the sex specific amelogenin gene. The X-chromosome contains a 6 base pair deletion compared to the Y-chromosome. This difference in length is detected by capillary electrophoresis on an ABI Prism 3130xl Genetic Analyzer (AB). The results were analysed with GeneMapper v3.2.1 (AB).

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[4] The capital letter 'N' refers to the size of the population analysed within this study. The lower-case letter 'n' refers to the size of the relevant (sub)sample.

Skeletal age at death

The skeletal age of non-adults was determined by means of dental eruption and mineralization (Ubelaker, 1989; WEA, 1980), ossification of the axial skeleton (Rauber and Kopsch, 1952; Wolff-Heidegger, 1954; Gray, 1989; Maat and Mastwijk, 1995), long bone length with or without epiphyses (Maresh, 1955), and status of epiphyseal fusion of the post-cranial skeleton (WEA, 1980; Brothwell, 1981). Since the average stature of the reference group of Maresh (178.2 cm) differed from the group under study, the long bone lengths were corrected proportionally before assessing the skeletal age of children.

For determination of the skeletal age of adults the Complex Method was used (Acsádi and Nemeskéri, 1970; Sjøvold, 1975; WEA, 1980). This method consists of the following age indicators: symphyseal face changes of the pubic bone, spongiosa architecture of the proximal end of femur and humerus, and determination of the endocranial suture obliteration (Nemeskéri et al., 1960; Broca, 1875). Additionally, for one individual we assessed the age at death by examining the remodelling of the subperiostal femoral bone tissue in a bone section under a microscope with a polarising filter, as described by Maat et al. (2002b; 2003; 2006).

Stature

The stature was calculated with the equations of Trotter and Gleser (1958) for females and both with Trotter (1970) and with Breitinger (1937) for males. In overviews and comparisons we used the statures that were uncorrected for age, which represent the statures that individuals are supposed to have had at the end of their growth period, before they start shrinking as a result of ageing (Maat, 2005).

Dental status and palaeopathology

Relevant abbreviations and formulas for the interpretation of the dental status are summarized below. The Decayed Missing index (DM index) gives the percentage of carious or ante-mortem lost teeth of all socket positions with inspected or ante-mortem lost teeth.

N erupted:	the assessed number of erupted regular teeth on the basis of the available space for socket positions in the jaws.
N inspected:	the number of inspected teeth.
N missing:	the number of missing socket positions and related teeth.
N unerupted:	the number of unerupted teeth.
N congenitally absent:	the number of congenitally absent teeth.
N supernumerary:	the number of supernumerary teeth.
N AM loss:	the number of ante-mortem missing teeth.
N PM loss:	the number of post-mortem missing teeth.
N carious:	the number of teeth with carious lesions.
N abscesses:	the number of abscesses.
N fistulas:	the number of fistulas.

$$\text{Ante-mortem loss (\%)} = \frac{\text{AM loss} \times 100}{\text{N erupted} - \text{n missing}}$$

$$\text{Post-mortem loss (\%)} = \frac{\text{PM loss} \times 100}{\text{N erupted} - \text{n missing} - \text{AM loss}}$$

$$\text{Caries frequency (\%)} = \frac{\text{N carious} \times 100}{\text{N inspected}}$$

$$\text{Abscess frequency (\%)} = \frac{\text{N abscesses x 100}}{\text{N erupted} - \text{n missing} - \text{AM loss}}$$

$$\text{DM index (\%)} = \frac{(\Sigma \text{ n carious} + \Sigma \text{ AM loss}) \text{ x 100}}{\Sigma \text{ n erupted} - \Sigma \text{ n missing} - \Sigma \text{ PM loss}}$$

Non-dental palaeopathology

The skeletons were examined for anomalies and palaeopathological changes, such as vertebral osteoarthritis (vOA), peripheral osteoarthritis (pOA), degenerative disc disease (DDD), diffuse idiopathic skeletal hyperostosis (DISH), deficiency diseases, fractures, etc. For further analysis some bones were examined by X-ray.

RESULTS

The main results of the 37 examined skeletons (i.e. sex, skeletal age at death, stature and palaeopathology) are shown per individual in Table 1.

Sex determination

From the 37 skeletons that were examined in this study, 36 were adults. By assessing the degree of sexualisation of the pelvis and the cranium 12 skeletons were determined to be male, 23 to be female and one remained indifferent (Fig. 3).

The anterior-posterior and maximum diameter results of the left and right femora and tibiae, are shown in Figure 4. The area of overlap for males and females was 25.5 – 30.0 mm (femur-APD), 27.5 – 30.9 mm (femur-max), 26.6 – 31.6 mm (tibia-APD) and 28.2 – 36.4 mm (tibia-max).

The measured left and right values for the skeleton of indifferent sex were: femur-APD: 30.2 and 31.7 mm, femur-max: 30.7 and 32.1 mm and tibia-max: 35.5 and 36.3 mm. The tibia-APD could not be measured for this individual. According to the femur-APD this skeleton was male, but according to the femur-max and the tibia-max the sex of this skeleton could not be determined.

DNA research was performed for eight of the adult skeletons. These analyses showed that the person for whom the sex could not be determined by means of physical anthropological methods was a male. The DNA analyses confirmed the sex of the other seven persons, who were concluded to be three males and four females by the physical anthropological research (Table 1).

Taken together, one skeleton was determined to be a child (3%), 13 skeletons were determined to be male (35%) and 23 skeletons were determined to be female (62%). The female : male ratio was 1 : 0.6 (n = 36).

Skeletal age at death

The skeletal age at death could be assigned to a specific ten-year interval (e.g. interval 0 = 0-9 year, 1 = 10-19 year, etc.) for 29 individuals (Figure 5). Within the sample no teenagers, being those over 10 and up to 20 years of age, and one child was found.

Based on the dental status, the skeletal age at death of the child was assessed to be 7 years plus or minus 24 months. Based on the corrected values for the long bone length according to Maresh (1955), the skeletal age of the child should be between 5.0 – 6.0 years. For this child, a skeletal age between 5.0 to 6.0 years (if not malnourished) would fit both methods.

The skeletal age at death of the adults, being those over 19 years of age, ranged from 22 to 62 years. The average skeletal age at death for adults was 43.2 years (n = 21) overall, 42.0 years (n = 10) for males and 44.3 years (n = 11) for females.

Stature

For males, the stature was calculated with both the equations of Breitinger (1937) and of Trotter (1970). According to the equations of Breitinger (1937) the average male stature was 173.6 cm (n = 11), and according to the equations of Trotter (1970) this was 175.9 cm (n = 11). To calculate female stature, the equations of Trotter and Gleser (1958) were used, which resulted in an average stature of 161.7 cm (n = 13). The statures for both males and females are shown in Figure 6a. The sex dimorphism between males and females showed a difference in stature of 11.9 cm based on the equations by Breitinger (1937) for males and by Trotter and Gleser (1958) for females.

Figure 6b shows the maximum femoral length of all left and right femora per sex. Comparisons similar to those for the stature could be made, resulting in an average maximum femoral length of 47.6 cm (s.d. = 2.93 cm, n = 17 (from 10 individuals)) for males and 43.0 cm (s.d. = 2.38 cm, n = 12 (from 9 individuals)) for females. The difference in maximum femoral length between males and females was 4.6 cm.

Dental status and palaeopathology

Table 1 gives the total number of teeth that were present or absent and shows some anomalies and pathological changes. An overview of these data, given in percentages, is shown in Table 3. Frequencies of additional dental palaeopathological conditions are shown in Table 4.

The overall degree of alveolar atrophy (i.e. absorption of the alveolar bone) and periodontitis (i.e. bacterial inflammation and destruction of dental supporting tissues) appeared to be slight to moderate, while the degree of calculus (i.e. tartar) formation was moderate to severe. Nine individuals (28%, n = 32) possessed one or more dental abscesses. Eight individuals (25%, n = 32) possessed one or more fistulas (i.e. an abnormal passageway through the bone tissue between an abscess and the exterior surface of the bone) associated with one or more dental abscesses.

As expected, the dental attrition at the occlusal plane of the molars showed a steady increase in the degree of attrition with increasing age. The natural differences in attrition between M1 and M2 and between M2 and M3, caused by their eruption sequence and the corresponding difference of about six years in functional age, were found. The relationship between the occlusal attrition and the age at death interval is shown in Figure 7 for the first (M1, n = 57), the second (M2, n = 61) and the third (M3, n = 38) molar.

Non-dental palaeopathology

Table 1 shows a summary of the palaeopathological changes that were found per individual. The frequencies of the palaeopathological changes and anomalies are shown in Table 4 and 5, respectively. The common palaeopathological changes, together with a selection of five remarkable palaeopathologies (i.e. asymmetrical spondylolysis, fish vertebrae, lumbar rib assimilation, coarctatio aortae and an enlarged right hemisphere, Figure 8) are discussed below.

PALAEOPATHOLOGICAL DISCUSSION

In order to comprehend the meaning of palaeopathological data, the concept of *frailty* has to be addressed first. Frailty is defined as an individual's age-adjusted relative risk of death (e.g. Vaupel et al., 1979; Vaupel, 1988). Differences in frailty exist because of differences in susceptibility and immune response to diseases that have genetic, environmental, socio-economic, behavioural, and other causes (e.g. Wood et al., 1992; Aalen, 1994; Robb, 2000). There are differences between men and women in terms of *morbidity* (i.e. risk of sickness) and *mortality* (i.e. risk of dead). It is known that males are frailer than women under equal conditions and that they are more susceptible to a wide range of diseases. Nevertheless, some diseases, such as osteoporosis, can disproportionately affect women (DeWitte, 2010).

Since morbidity and mortality are selective, the deceased are a biased sample; they were selected out of the living population (e.g. Bello et al., 2006). The expected frequency of the palaeopathological conditions will therefore be greater among the dead than among the still living. Since the prevalence of diseases increases with age, it is furthermore expected that populations with a high proportion of elderly individuals will develop more palaeopathological conditions than populations with a high proportion of young individuals.

Only a small fraction of pathological conditions develop bony lesions (i.e. disease markers visible on bones) and most of these lesions are related to chronic pathological conditions. Frail individuals (i.e. persons who are vulnerable for disease), who become seriously ill, die quickly and thus do not survive long enough to develop bony lesions. The less frail individuals with a relatively good immune response may survive the illness and therefore develop bony lesions. This is known as the 'osteological paradox' and it implies that the presence of (healed) bony lesions may be indicative of a relatively good overall health (e.g. Wood et al., 1992).

Dental status

In our study, the post-mortem tooth loss was 12.5%, which is low in comparison to other studies. This is an indication for the amount of care taken by the (amateur-) archaeologists during the excavation and subsequent handling of the skeletal remains.

In contrast to the low post-mortem tooth loss, the ante-mortem tooth loss of 23% was high when compared to the reference populations in Table 6. This ante-mortem tooth loss is typically caused by caries (i.e. bacterial demineralization of the hard tissues of the teeth). The Decayed Missing index (DM index) of 43.0%, together with the dental abscess and fistula percentages, were high as well. This is an indication that tooth decay was a serious problem within our sample. On the other hand, the occurrence of alveolar atrophy and periodontitis was low to moderate. The overall dental status showed no well-defined sex specific distribution.

Mechanical traumata

In 43% of the individuals in our study (N = 37) healed traumata were found. This is a comparable percentage as seen within the adult citizens buried in Vlaardingen (Groen and de Ridder, 2006) and Gorinchem (Maat and Mastwijk, 2000), but much higher compared to the studies in Breda (Rijpma and Maat, 2005) and Dordrecht (Maat et al., 1998) (Table 7). The

detected traumata included cranial impression fractures, rib fractures, vertebral compression, impression, and avulsion fractures, spondylolysis (i.e. mechanical stress fracture of a vertebral arch), a possible nose fracture and a couple of (possible) long bone fractures. All encountered traumata fell within the range that could be expected within a Late Mediaeval urban population. An example of a rare asymmetrical spondylolysis is shown in the final paragraph ("Remarkable palaeopathology") of this chapter.

Infections

Four individuals (11%) within our sample showed indications for non-dental infections, which is comparable to the percentage discovered within the "Oude en Nieuwe Gasthuis" (Onisto et al., 1998) (Table 7). Cribra orbitalia and cribra femora (see next sub-paragraph) were not taken into account in this number, in order to be able to compare our results to other studies. The detected infections were: periostitis (n = 2), osteomyelitis (n = 1) and sinusitis maxilliaris (n = 1). Periostitis may be caused by the infection of the periosteal membrane due to a perforation of the skin (i.e. unilateral periostitis) or a haematogenous infection (i.e. bilateral periostitis). Osteomyelitis is usually initiated by a haematogenous infection of the bone marrow, and sinusitis maxilliaris is caused by sinus infection of the maxilla.

Since only 11% of the individuals showed indications for (non-dental) infections, it is unlikely that the individuals in our sample were exposed to heavy overcrowding or strong unhygienic conditions (e.g. Roberts & Manchester, 1997). However, most infections heal quickly or, in frailer individuals, lead to a quick death. It is therefore also possible that the frailer individuals within our study did not have enough time to develop bony lesions (e.g. Robb, 2000; Wood et al., 2002). Summarizing, the number of excavated individuals with (non-dental) infections does not reflect the number of individuals with infections within the living population, but should be seen as the minimum number of individuals with infections within the deceased population.

Cribra orbitalia and cribra femora

One male in our sample showed cribra orbitalia (i.e. a porotic lesion in the bony orbital roof) and three additional individuals (8%, n = 37) showed cribra femora (i.e. a porotic lesion in the antero-inferior surface of the femoral neck).

Cribra orbitalia and cribra femora are often defined, in out-dated archaeological literature, as indicators of chronic iron-deficiency anemia caused by malnutrition, chronic blood loss, diarrheal disease, or by parasitic infection. However, iron deficiency cannot induce the bone marrow hyperplasia necessary to cause cribra formation, since one of the building blocks (iron) is deficient. For a hyperplasia a haemolytic process is needed to deliver sufficient amounts of components. Worldwide, the best candidate for such an affection is infection by malaria. Up to the end of the Second World War, malaria was endemic in the Low Countries (with numerous non-flowing water masses for the mosquitos). The pathological changes that are associated with cribra orbitalia and cribra femora may also be associated with some very rare affections, such as scurvy, rickets, chronic cranial infections and haemangiomas (e.g. Wapler et al., 2004, Walker et al., 2009).

Arthropathies

In our study, a distinction was made between degenerative disc disease (i.e. DDD) and osteoarthritis (i.e. vOA and pOA).

Degenerative disc disease (DDD)
Degenerative disc disease (DDD), also known as vertebral osteophytosis (VO), is associated with senescent deterioration of the intervertebral discs due to the dehydration and degeneration of the fibrocartilaginous tissue of the discs. The decrease in the intervertebral disc height leads to altered patterns of stress and weakening of the skeletal structure. Due to irritation of the periosteal membrane covering the vertebral bodies, marginal osteophyts are formed adjacent to the affected endplates, which effectively block further herniation of the discs. The development of DDD is induced by a combination of risk factors and, epidemiologically, its frequency increases with (skeletal) age (Jurmain, 1999; Rogers, 2000).

The DDD frequency in our sample was 64% (n = 36), which is similar to the percentage found within the Dordrecht population (Maat et al., 1998) (Table 7). However, our percentage is lower than that for the citizens buried in mid-Mediaeval Vlaardingen (Groen and de Ridder, 2006) and the Canons buried within the chapel of Saint Servaas in Maastricht (Janssen and Maat, 1999). The DDD found in our study seems to affect more males than females, since 57% of the females (n = 23) and 77% of the males (n = 13) showed indications of this disease. This might be due to a sexually based division of labour and therefore of labour associated spine load (e.g. Jurmain, 1999; Rogers, 2000; Faccia and Williams, 2008).

Osteoarthritis
Osteoarthritis is the result of degeneration of the cartilage of the synovial facet joints of the vertebral arches (i.e. vertebral osteoarthritis or vOA) and the non-spinal peripheral synovial joints (i.e. peripheral osteoarthritis or pOA). The development of vOA and pOA is associated with a combination of risk factors, although, besides genetic predisposition, the primary contributing factors seem to be mechanical stress and high (skeletal) age (e.g. Radin, 1982; Peyron, 1986, Dieppe, 1990; Maat et al., 1995; Larsen, 1997; Jurmain, 1999; Rogers, 2000).

In our study, 67% (n = 36) of the individuals showed signs of vOA. This is a high percentage when compared to the reference populations in Table 7. This disparity cannot be explained by demographic differences between our sample and the reference populations, but might be a result of our meticulous screening of the bones. Eight men (62%, n = 13) and 16 women (70%, n = 23) in our sample were affected with vOA. Four men (50%, n = 8) and twelve women (75%, n = 16) presented the cervical type of vOA, which appeared to manifest itself more often in women than in men. The thoracic and lumbar types of vOA showed no sex specific distribution, which underlines that osteoarthritis of the lower spine, in contrast to DDD, is partially due to genetic predisposition (e.g. Robbins, 1999; Maat and Mastwijk, 2000).

Since pOA percentages are not separately taken into account within most reference populations (Table 7), it is unclear what the significance is of the high percentage found within our sample (i.e. 75%, n = 36) compared to the studies in Gorinchem (Maat and Mastwijk, 2000) and Vlaardingen (Groen and de Ridder, 2006). Most individuals in our sample showed signs of more than one location of pOA. There seems to be a slight association between sex and the development of pOA in a specific location (e.g. the development of pOA in elbows and shoulders is more frequent in females). This could be the result of sex specific division in labour and/or behaviour (Jurmain, 1999). This hypothesis may be further substantiated by the fact that the cervical type of vOA seems to be more frequent within females than in males.

Deficiency diseases

Linear enamel hypoplasia
One male in our study showed linear enamel hypoplasia (i.e. horizontal growth arrest lines visible on the buccal surface of teeth). Linear enamel hypoplasia can be caused by any health insult, but is most likely the result of a limited period of severe sickness and/or malnutrition (e.g. Suckling, 1989; Goodman and Rose, 1990; Goodman and Rose, 1991; Larsen, 1997). The fact that only one individual in our sample showed linear enamel hypoplasia suggests that the individuals buried within the cloister garth have not been exposed to serious malnutrition or chronic illness during their childhood years.

Rickets and osteomalacia (vitamin D deficiency)
When the deformity of bones (especially femora, tibiae and fibulae) is assumed to be a sufficient criterion to diagnose healed rickets or osteomalacia (i.e. the "adult form" of rickets), then four females (17%, n = 23) and two males (15%, n = 13) in our sample showed signs of these diseases. This seems to be a high percentage (16%, n = 37) when compared to the reference populations in Table 7. The cause of this discrepancy remains unclear, since it cannot be explained by the demographic (or palaeopathologic) differences.

Rickets can be caused by a variety of factors, all of which affect the metabolism of vitamin D. Historically, the most important cause is an inadequate acquisition of vitamin D, due to an insufficient exposure of the skin to (ultra-violet) sunrays or a vitamin D deficiency in the diet (Ortner and Mays, 1998; Brickley, 2000; Mays et al., 2006). Rickets manifests itself, amongst other things, in deficient mineralization of the bone matrix. Under mechanical stress by bodyweight and muscle tension, this leads to bending of the shafts of the long bones in the legs, the spine, the pelvis and, in very young children (due to crawling), in the arms. Osteomalacia manifests itself in (pseudo)fractures and in deformations of the scapulae, vertebral column, ribs, sternum and pelvis, or in the bending of the shafts of the long bones (Brickley, 2000; Brickley et al., 2005; Brickley et al., 2007).

Although deformities of long bones can be caused by different factors (Brickley et al., 2010), they most likely represent healed rickets from the growth period. It is also plausible, however, that these deformities are related to osteomalacia in adults, possibly due to serious medical conditions, such as cancer, hypertension or cardiovascular hearth disease (Holick, 2005), or the lack of skin exposure to direct sunlight (Brickley et al., 2006; Brickley et al., 2010).

DISH
Depending on the diagnostic criteria that were used, zero to six individuals in our sample (0–17%, n = 35) showed indications for DISH (Diffuse Idiopathic Skeletal Hyperostosis). These criteria vary strongly between researchers (Mays, 2000; Mays, 2006; van der Merwe, 2012). According to Julkunen et al. (1971) an ankylosis of a minimum of two vertebrae is needed to diagnose DISH. Rogers and Waldron (1995) diagnose DISH only if a minimum of four (thoracic) vertebrae are ankylosed. In all studies performed at Barge's Anthropologica (e.g. Onisto et al., 1998; Janssen and Maat, 1999; Maat et al., 2002a; Rijpma and Maat, 2005) and in the study performed by Groen en de Ridder (2006) DISH was diagnosed in individuals who showed signs of spinal ligamentous ossifications (i.e. bony outgrows) in two or more thoracic and/or lumbar vertebrae and/or in individuals who lacked (almost all) thoracic

vertebrae due to taphonomic effects that nevertheless possessed extra-spinal, systematic ossifications at ligament and/or tendon insertions.

In our sample, not one individual (n = 35) could meet the diagnostic criteria for DISH as proposed by Rogers and Waldron (1995), and only two female individuals (6%, n = 35) met the diagnostic criteria as proposed by Julkunen et al. (1971). However, six individuals (17%, n = 35) met the diagnostic criteria as used in the Barge's Anthropologica series (e.g. Onisto et al., 1998; Janssen and Maat, 1999; Maat et al., 2002a; Rijpma and Maat, 2005).

DISH is a progressive (metabolical) disorder that is characterised by the ossification of connective tissue. Especially osssification of the right lateral aspect of the thoracic anterior longitudinal ligament, together with the tendency to develop extra-spinal entheses (i.e. ossified ligaments or tendons) and to ossify extra-spinal cartilaginous structures is highly characteristic (e.g. Resnick et al., 1975; Littlejohn and Urowitz, 1982; Larsen, 1997; Cammisa et al., 1998). The prevalence of DISH increases with (skeletal) age and is more common in males than in females. DISH is also linked to high body weight and to late onset of (type II) diabetes (e.g. Julkunen et al., 1971; Crubézy, 1990; Klemperer, 1992, McAlindon et al., 1996; Mata et al., 1997; Rogers, 2000).

The findings of Waldron (1985), Janssen and Maat (1999), Rogers and Waldron (2001) and Jankauskas (2003) indicate a raised prevalence of DISH in monastic and high status burial grounds. This is seen as evidence of over-eating and consequent obesity. In Mays (2000) and Mays (2006) it is questioned, however, whether the link between high body mass and DISH, as found in clinical studies, is strong enough to be used as an indicator of obesity in archaeological skeletal samples. According to Mays (2006), no statistically valid studies are published that point towards a higher rate of DISH among monastic mediaeval burials, compared to non-monastic mediaeval burials.

In view of these comments, our monastic maximum DISH percentage of 17% is relatively low, when compared to others (Table 7). In addition, the non-monastic DISH percentage of 42% within the Gorinchem population (Maat and Mastwijk, 2000) is relatively high.

Remarkable palaeopathology

A number of individuals showed remarkable palaeopathologies and a selection of five cases is described below. The first examples are spine-related palaeopathologies and the latter three are congenital malformations.

Asymmetrical spondylolysis

Spondylolysis is the separation of the arch mostly within the pars interarticularis of a vertebra, resulting in two parts: (1) a ventral part formed by the vertebral body, the pedicles, and the superior articular processes, and (2) a dorsal part formed by the laminae, spinous process and inferior articular processes (Aufderheide, 1998). Spondylolysis of the lower back is a vertebral fracture that is unique to humans, for it is related to those anatomical features that facilitate an upright posture and bipedal locomotion in our species, such as the lumbar curve (Merbs, 1989). Earlier concepts regarded spondylolysis as a congenital malformation due to a developmental fusion failure. However, Stewart (1953) and later Merbs (1989) demonstrated that the occurrence of spondylolysis increases with age and varies greatly between populations. They suggested that hyperflexion of the lumbar spine combined with simultaneous extension of the knees causes repeated fatigue micro-trauma of the pars

interarticularis resulting in stress fractures. Spondylolysis is usually bilateral and symmetrical. As shown in Figure 8a, the spondylolysis found in a man, whose age at death was estimated between 20 and 26 years, is asymmetrical. This cannot be caused by an ossification union failure, and probably resulted from a stress fracture, as well.

Osteoporosis (fish vertebrae)
Osteoporosis is a disease characterized by an abnormal decrease in the amount and internal architectural arrangement of bone tissue. Such changes in bone structure result in micro-architectural deterioration of trabecular support structures and a reduction in density (Brickley, 2000). It leads to decreased skeletal strength and to an undue susceptibility to fracture. When vertebral bodies are affected by osteoporosis and the axial pressure becomes too large for their strength, they may collapse under the pressure of the enclosing biconvex intervertebral discs. Such vertebral bodies may look like fish vertebrae with the characteristic biconcave shaped hollow endplates (Taylor, 1996). In one woman, whose age at death was estimated between 53 and 59 years old, two very clear examples of such vertebrae with hollow endplates were found (Fig. 8b).

Lumbar rib anlage concretion
In a woman whose estimated age at death was between 49 and 55 years old, three lumbar vertebrae were involved in the fusion of transverse process tissue with rib anlagen and formed a concretion of bone tissue parasagitally to the right side of the lumbar spine (Figure 8c). This concretion was attached to the third lumbar vertebra and showed a joint surface with the 'rib anlagen' of the second and the fourth lumbar vertebrae. Nowadays, such a congenital segmentation disorder is sometimes found during routine abdominal radiography.

Coarctatio aortae
Coarctatio aortae is a narrowing constriction in the arch of the aorta where the ductus arteriosus is supposed to halt its obliteration after birth. These days, many infants with coarctatio aortae with or without a persistent ductus arteriosus do not survive the neonatal period without surgical intervention. The life expectancy may be different in case of a mild coarctatio aortae without a persistent ductus arteriosus. Most of these children remain asymptomatic, and the disease may go unrecognized until well into adult life. Typical for such cases is hypertension in the upper extremities in combination with weak pulses and a lower blood pressure in the lower extremities associated with manifestations of arterial insufficiency. Particularly characteristic in adults is the development of a strong collateral circulation between the precoarctation arterial branches and the postcoarctation arteries through enlarged intercostal and internal mammary arteries and the radiographically visible erosions (notching) of the undersurfaces of the ribs (Robbins, 1999). As shown in Figure 8d, this notching was visible in the ribs of a woman whose age at death was estimated between 34 and 40 years old. Based on her age at death, the coarctatio aortae in this woman was probably mild.

Enlarged right hemisphere
Figure 8e shows the skull of a woman, whose age at death was estimated between 38 and 60 years old, viewed from the left. The corresponding X-ray (Fig. 8f) is viewed from above. Both Figures show a malformation of the skull on the right side. Such a malformation could be caused by hemimegalencephaly, which is a rare congenital malformation characterized by overdevelopment of all or part of one cerebral hemisphere, whereas the opposite hemisphere is usually normal (Sener, 1995). It is generally assumed that hemimegalencephaly is the result of a defect that leads to the excessive proliferation of both neurons and astrocytes.

There are no clear environmental causes, and no associations with known chromosomal abnormalities (Leventer, 2008). The clinical characteristics of hemimegalencephaly are typically: (1) intractable partial seizures starting in the neonatal period or early infancy, (2) hemiparesis, and (3) developmental delay.

PALAEODEMOGRAPHIC DISCUSSION

In every physical anthropological study it is necessary to investigate whether the studied sample represents the society from which it was drawn in order to assess whether the obtained data realistically represent the living population. Besides the socio-cultural context, taphonomic processes may have influenced the survival of the studied sample and should be taken into account (e.g. Bocquet-Appel and Masset, 1982; Bello and Andrews, 2006; Groen, in prep.). In addition, it is evident that the manner of excavation and the subsequent cleaning and storage of the excavated skeletal material influences the completeness and the (differential) survival of skeletal elements and, therefore, the composition of the skeletal sample.

The *socio-cultural context* (i.e. the sum of all learned believes, attitudes and behaviours that influence how a person thinks and behaves) determines many factors in burial practices, like the used funerary practices, coffin designs and grave types, as well as the spatio-temporal patterns encountered within the cemeteries (e.g. Andrews and Bello, 2006; Groen, in prep.). The plots where individuals were buried were not assigned randomly; they tend to cluster by gender, religious background, and socio-economic status of the deceased. For example, it is known that Christians in the Late Mediaeval period reserved special plots for lepers, paupers, criminals and unbaptised children. Burial within a cloister garth was perceived as more prestigious than burial within a regular parish cemetery, since it meant that payers for the soul of the deceased would be included in the daily prayers performed at the monastery or nunnery. Only certain religious or socio-economic groups were therefore, generally speaking, buried within a cloister garth. Additionally, the religious or socio-economic status of a person was not static. It could change during life in accordance with occupation, wealth, marriage, affiliation and experience. Besides, individuals who died during a disease outbreak (e.g. plague) were often buried in burial plots that were specially prepared for this purpose, often disregarding their religious or socio-economic status.

Taphonomy is defined as the study of processes related to disintegration and destruction, or the lack thereof, of organic and inorganic tissues, the way this degradation affects the (differential) survival of skeletal material, and in which manner this survival affects the physical anthropological interpretation. First of all, taphonomy is concerned with the physical characteristics of the diseased individual that are relevant to the decomposition process. These are the so-called *intrinsic taphonomic variables*, consisting of sex, age and constitution. Since they are related to the anatomical and physiological structure, they also influence the preservation potential (i.e. taphonomic strength) of a person's skeletal material after burial. It is known that taphonomic strength is associated with density and robusticity of bone (Walker et al., 1988; Galloway et al., 1997; Willey et al., 1997; Bello et al., 2006; Wittwer-Backofen et al., 2008; Groen, in prep.). Bones with low bone density or high proportions of cancellous bone, i.e. bones of the young and elderly in general, as well as the epiphyses of long bones, the vertebral bodies and the small bones of hands and feet in particular, possess low taphonomic strength. As a consequence, they tend to be less well preserved in the archaeological context. Secondly, taphonomy is dependent on the socio-cultural and environmental contexts that affect the remains after death. These so-called *extrinsic taphonomic variables* are related to the manner and location of the burial. The burial manner (e.g. in a shroud, in a wooden coffin, or in a stone sarcophagus) at different locations (e.g. in sandy soil, or in clay) is associated with different (micro-)environments, and therefore with differences in bone preservation in the archaeological contexts (e.g. Gordon and

Buikstra, 1981; Henderson, 1987; Mant, 1987; Micozzi, 1991; Mays, 1992; Groen, in prep.). Different depths of inhumations may be associated with different environments and subsequent bone preservation. For example, inhumations located above the groundwater level or directly beneath a floor (amongst others) are destroyed more easily due to access of oxygen, vegetation and later disturbances by humans.

In our study only 84 out of the primary 112 interments (75%) excavated within the corridors of the cloister garth had sufficient taphonomic strength to survive (almost) completely.

Sex

When no (analysable) pelvis was available for sex determination, the sex was determined by means of caput analysis only. Caution has to be taken with this method, since it is known that young adult males generally have less well-defined and less robust cranial features than the mid-adult ones. With increasing age the female cranio-facial markers may be altered as well and become more masculine, due to alteration of menopausal hormones (e.g. Meindl et al., 1985; Walker, 1988; Meindl and Russel, 1998; Walrath et al., 2004). In addition, Dutch females possess relatively masculine jaws, compared to other European countries (Maat et al., 1997). Nevertheless, the used physical anthropological sex determination methods seem to be sufficiently reliable (Molleson and Cox, 1993; Maat et al., 1997; Meindl and Russel, 1998). For the skeletons in this study on which DNA analysis was performed, the sex determination results were confirmed.

The adult sex ratio of 35% males versus 62% females (and 3% children) was remarkable since Koningsveld was a nunnery and, therefore, it could be expected that its cloister garth was used solely for the burial of deceased nuns. Although it is thinkable that some monks from the Mariënweerd monastery stayed in the nunnery (e.g., the priest and the prior), their presence would not explain the percentage of males found in the sample. One option might be that the benefactors of the priory, males from a praying community, males with specific wills, or males who were relatives of the nuns were also buried within the cloister garth. This would imply that the nuns were accommodating lay burial. Another option could be that the Premonstratensian lay-brothers who worked at the Old and New Infirmary (Dutch: *Oude - en Nieuwe Gasthuis*) were buried in the garth. An alternative explanation may be that the male to female ratio in our sample is distorted, due to the expected lower taphonomic strength of the female skeletons, which would lead to an underrepresentation of older women (Groen, in prep.). The presence of the skeletal remains of a five to nine years old child in the garth might be explained by the fact that some nunneries accepted children to be brought up as nuns (Burton, 1994). It is also possible that this child was a relative of one of the nuns, or of one of the benefactors or benefactresses of the priory.

Age at death

The average skeletal age at death of the deceased over the age of 19 was 43.2 years overall (n=21), 42.0 years for males (n=10) and 44.2 years for females (n=11) (Table 1, Figure 5). This average skeletal age at death is comparable with that found in most studies covering the same period, both in Delft and in other Dutch cities (Table 8). This is remarkable, since these studies are based on skeletal populations with different religious background and socio-economic status. Additionally, the average skeletal ages at death in these studies do not seem to correlate with the decline of the average (male) stature during the Mediaeval and post-Mediaeval period, as described in the next subsection (Westen, 2002 and Maat, 2005).

The similarity in average skeletal age from different skeletal populations may depend, in part, on the methodological and statistical restrictions regarding the regression based aging methods used in our and other studies. It is known that the mathematics of regression based aging methods often overestimate the age of (young) adults (age intervals 20 to 50 years) and systematically underestimate the age of the elderly (intervals above 50 years of age). Furthermore, the regression based ageing methods are, to some extent, biased in the direction of the age structure of the known reference sample (i.e. *the concept of mimicry*) from which a particular method was devised (e.g. Bocquet-Appel and Masset, 1982; Walker et al., 1988; Aykroyd et al., 1997; Aykroyd et al., 1999; Holman et al., 2002; Schmitt et al., 2002; Komar, 2003; Corsini et al., 2005; Djuric et al., 2007; Samworth and Gowland, 2007; Kimmerle et al., 2008; Meinl et al., 2008; Wittwer-Backofen et al., 2008). The aging method used in our study (i.e. the Complex Method) seems to favour an age distribution around age interval 40 to 50 (Groen, in prep.). In our sample population, for 29 individuals an age interval could be assigned (based on two or more age indicators); 21 of them were distributed within the age categories 3, 4 and 5 (30-60 years) and only one individual surpassed the skeletal age at death of 60 years (Fig. 5). Although this age distribution could mirror the age distribution in the once living population, it is more likely that it is linked to the methodological preference of the Complex Method to group individuals into the age intervals around 40 to 50 years.

It is important to realise that an average skeletal age at death is not the same as an average chronological (or calendar) age at death. Although there is a strong relationship between the two, with increasing age the skeletal age at death shows a greater spread around the chronological age at death. Whether the average skeletal age at death is representative for the living population from which the sample was derived is questionable, since its outcome depends on the socio-cultural context and the taphonomic processes associated with the sample. Due to osteoporosis of the bone tissue, the skeleton becomes more porous and fragile with increasing (chronological) age. Bones of postmenopausal females may furthermore be more severely affected by osteoporosis and therefore become even more porous. Consequently, skeletons of postmenopausal females are frailer (and thus have lower taphonomic strength) than those of older males and tend to be underrepresented in the skeletal sample consisting of (almost) complete skeletons. It may therefore be expected that the average skeletal age at death concerning all females buried in the cloister garth (when corrected for the taphonomic bias) will be higher than the average skeletal age estimated from our sample population (Groen, in prep.).

Stature

The sex dimorphism between the average stature of males and females of 11.9 cm (173.6 cm or 175.9 cm for males, and 161.7 cm for females) falls within the expected stature difference between sexes, which is 9 to 13 cm (Oppers, 1966; van Wieringen, 1979). According to Wurm and Leimeister (1986) the equations by Breitinger (1937) produce a more realistic stature estimate for European men born “north of the Alps”. It seems plausible that the reference group of Breitinger, consisting of 2400 modern German men, is a better reference group for the Late Mediaeval Dutch population, than the more heterogeneous group of Trotter (1970) that consisted of modern “White American” men (Ross and Koningsberg, 2002; Maat, 2005; Kimmerle et al., 2008).

The average adult stature is considered to be a reliable indicator of the general health and hygienic conditions of a population and thus of the socio-economic background and status (e.g. van Wieringen, 1972; van Wieringen, 1979; Roede, 1985). When compared to the

reference populations in Figure 9 and Table 9, the males who were buried in the cloister garth of the Koningsveld Priory thus seem to have had a higher socio-economic background than the females, whose average adult stature seems to point towards an average socio-economic background.

It is questionable whether the average statures mentioned above correspond well with the average statures of the entire Koningsveld population (Groen, in prep.). Next to the fact that these statures were based on a small sample size, a first concern is that the stature estimation methods used in our study relied on sets of equations obtained from different combinations of long bones, due to the taphonomic bias in the availability of the skeletal parts. Since different combinations of long bones were used for calculating the stature, methodological and statistical biases were introduced (e.g. Maat, 2005). It is known that the length of long bones from the upper extremities is less influenced by the environmental variables than those from the lower extremities (Kemkes-Grottenthaler, 2005). An additional concern with the Breitinger (1937) method is that this method relies on (up to four) individual stature equations, all including a different standard deviation. The individual equations are subsequently averaged in order to produce an 'overall' stature estimate and the highest standard deviation is used as the standard deviation for all equations. However, from a statistical point of view, this is not correct. A third and final concern is that our female stature estimation method, developed by Trotter & Gleser (1958), depends on cadaver data derived from the ill-nourished North-American Terry Collection (Jantz et al., 1994; Meadows and Jantz, 1995; Kimmerle et al., 2008). This method is therefore biased towards combinations of relatively short (due to malnourishment) long bones (i.e. the concept of mimicry).[5]

A possible solution to avoid the above-mentioned statistical and methodological concerns is a direct comparison of long bone lengths, for example the maximum length of a femur (Maat, 2005; Westen, 2002). The femur is a good indicator of stature and its length is also strongly influenced by environmental factors (e.g. Meadows and Jantz, 1970; Wilson et al, 2010). The average maximum femoral length in our study was 47.6 cm for males and 43.0 cm for females, with a difference of 4.6 cm. Like the calculated statures, the average male femoral length is long, when compared to the male reference populations (Fig. 10a and Table 10). On the other hand, the average female femoral length is relatively short, when compared to the female reference populations (Fig. 10b and Table 10). This is remarkable since the historical sources indicate that the Koningsveld nuns derived from noble families, and were hence expected to be taller than average.

A general methodological concern regarding all average stature estimations in skeletal samples is that the non-damaged long bones of the elderly, especially women, will probably be underrepresented in the skeletal sample, due to the low taphonomic strength of these bones (Groen, in prep.). Furthermore, Kemkes-Grottenthaler (2005) has showed that individuals who died young (20-40 years), on average, have shorter statures than individuals who have survived to the age of maturity (40-60 years), which is especially true when the stature estimation is based on tibiae and femora (Wood et al., 1992; Duyar and Pelin, 2003). The association between a shorter stature (due to stress or malnutrition during childhood) and a shorter lifespan of a person makes it imaginable that the taphonomic damage of the longer (and therefore often older and thus frailer) long bones reduces the average stature estimation of a skeletal population. Therefore, the average female stature calculated from our sample

[5] Additionally, caution is advised when using the Trotter & Gleser (1952) formulae related to the tibia length measurements, especially the maximum length (e.g. Jantz et al., 1994).

might be on the short side when compared to the average stature of the total female population buried within the cloister garth.

Religious and socio-economic status

Although the correlation between the religious and socio-economic status (i.e. the rank, honour and prestige attached to one's position within society), and the degree of public health is well-documented in modern populations (e.g. Tanner, 1986; Tanner, 1992; Steckel, 1995), there is lack of well-defined skeletal markers associated with 'poor hygiene and malnutrition' or 'health and a plentiful diet' within studies concerning archaeological skeletal populations. An additional concern is that the skeletal markers that seem to be associated with 'poor hygiene and malnutrition' (e.g. short stature, Harris lines, linear enamel hypoplasia, rickets and bilateral periostitis of the tibiae) and those that seem to be associated with 'good health and a plentiful diet' (e.g. high stature, low frequency of non-specific haematogenous infections, certain types of pOA, DISH and gout), are both often detected in one population, or even in one individual. The 'poor hygiene and malnutrition' markers that may have developed during childhood could therefore (seemingly) contradict with the 'good health and plentiful diet' markers developed during adulthood. For example, three individuals in our study (N = 37) that showed (possible) signs of healed rickets, or bilateral periostitis of the tibiae also showed bony lesions indicative for DISH. In addition, the six females in our sample that met the 'Barge's Anthropologica' diagnostic criteria for DISH had an average stature of 158.7 cm, which is 3 cm below the average female stature in our sample.

We should therefore remain cautious when interpreting the socio-economic status or the nutritious state of an archaeological skeletal population (Groen, in prep.). First of all, most skeletons cannot be dated with such a precision that allows distinguishing the different socio-economic fluctuations, which are associated with particular time periods within the sample population. As a consequence, the palaeopathological diagnoses tend to describe an "average" or "spread out" nutrition and health status of a population, often covering a time span of five or more generations. Second, the prevalence of diseases and the health risk individuals have had are context specific; diseases have a synergistic relationship to the environment in which the individuals lived. Bone markers are caused by a complex network of intrinsic, socio-economic and biological factors and possess a certain amount of individual variability. Since it is unknown how susceptible and frail the studied individuals were to a specific disease, it is difficult to assign certain diseases to a specific socio-economic background and status meaningfully. Finally, taphonomic processes could be responsible for the destruction of the once present skeletal markers. This would especially affect the skeletons of women and older, and therefore possibly frailer, individuals.

CONCLUSION

In the cloister garth of the Koningsveld Priory, both men and women were interred. Our study population represents about one third of the total primary interments excavated from the cloister garth, and consists for about one third of men, two third of women and includes one child. The overall (health) status of the men seems to be above average, based on their high femoral length and stature, while that of the women appears to be average. For the women, this was not expected, since historical sources indicate that they derived from noble families. With increasing age, bones become more porous and therefore more susceptible for damage, before being analysed. The bones of women are less robust than those of men, and in addition may be severely affected by osteoporosis, which makes them even more vulnerable. The healthiest, and therefore probably longer, individuals become older; as a result their bones, especially those of the women, are usually underrepresented in a skeletal sample. This not only effects the sex distribution and average stature measurements, but also the average age at death estimations. These estimations are additionally affected by methodological biases, since the available methods, like the Complex Method that we used in this study, tend to overestimate the age of the young and underestimate the age of the elderly. This might explain the average age at death of 43.2 years in our study, which is comparable to the findings in studies concerning groups with (much) lower socio-economic status in the same time period. In conclusion, taphonomic variables, both intrinsic (i.e. structural bone properties) and extrinsic (e.g. socio-cultural differences in funerary practices or location of burial), recovery and handling of the bones and methodological biases will alter the sex, stature and age-class construction of the analysed skeletal population. Therefore, this skeletal population does not reflect the once buried population directly.

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FIGURES AND TABLES

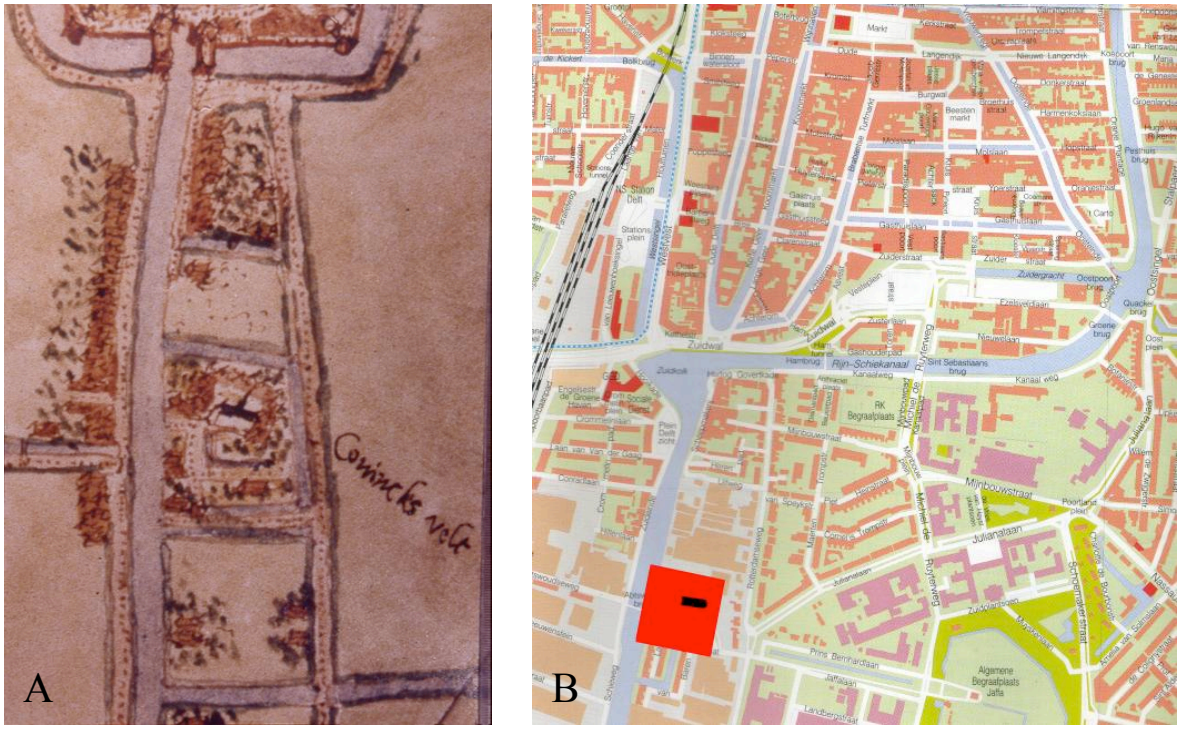


Figure 1. (A) Historical map by Jacob van Deventer picturing the location of the Koningsveld site in Delft (ca. 1560). (B) Modern map of Delft picturing the location of the Koningsveld site (red square).


N
W
E
S
A
0
5
10
20 m


N
W
E
S
B
0
2,5
5
m

Figure 2. (A) The excavation plan of the 2002 Koningsveld campaign. (B) Part of the excavation plan picturing inhumations discovered in the cloister garth. (C) Part of the excavation plan picturing the sampled inhumations from the cloister garth in blue, and the other inhumations in grey

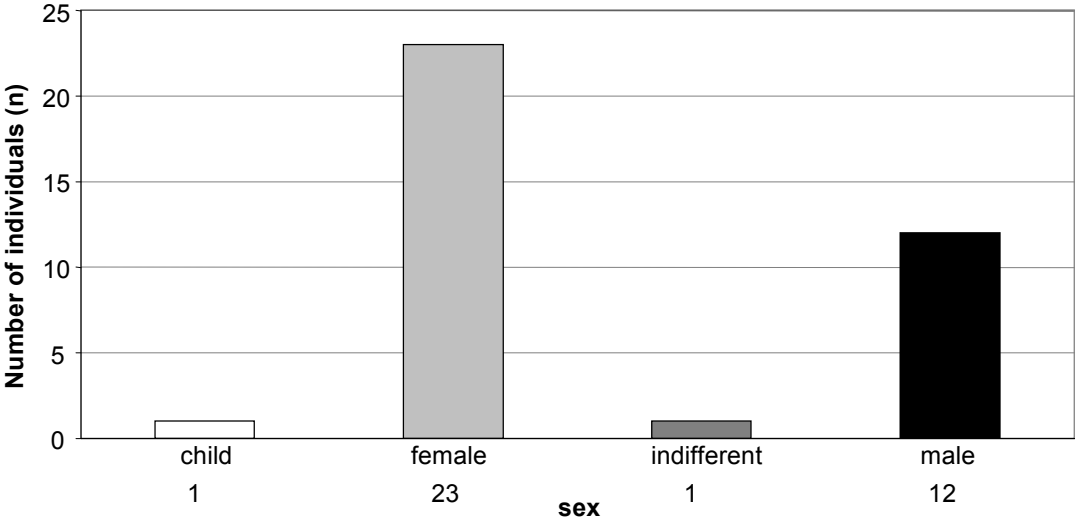


Figure 3. Sex distribution based on the degree of sexualisation of the pelvis and the cranium.

See next page for Figure 4.

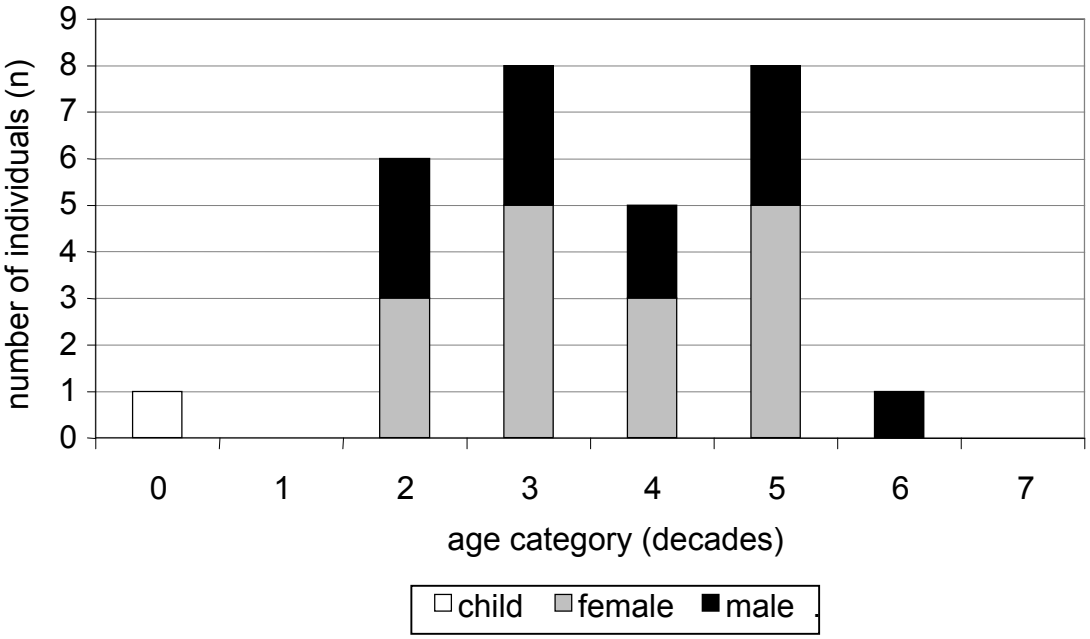


Figure 5. Age at death distribution for males, females and one child, for whom at least 2 age indicators could be analysed. Ages are categorised per decade (e.g. 2 = 20-29 years of age at death).

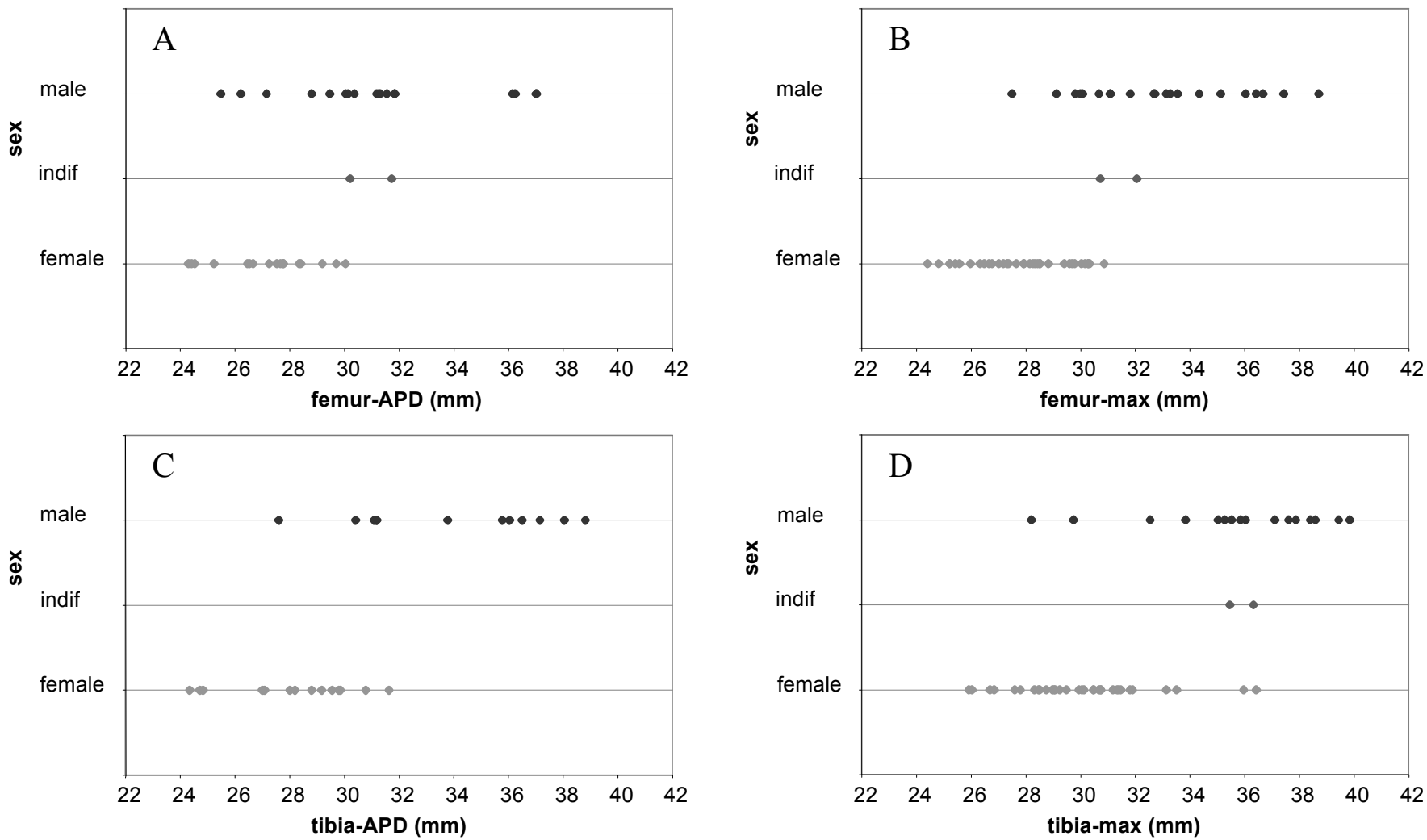


Figure 4. (A) APD of the femur. (B) Maximum diameter of the femur. (C) APD of the tibia. (D) Maximum diameter of the tibia.

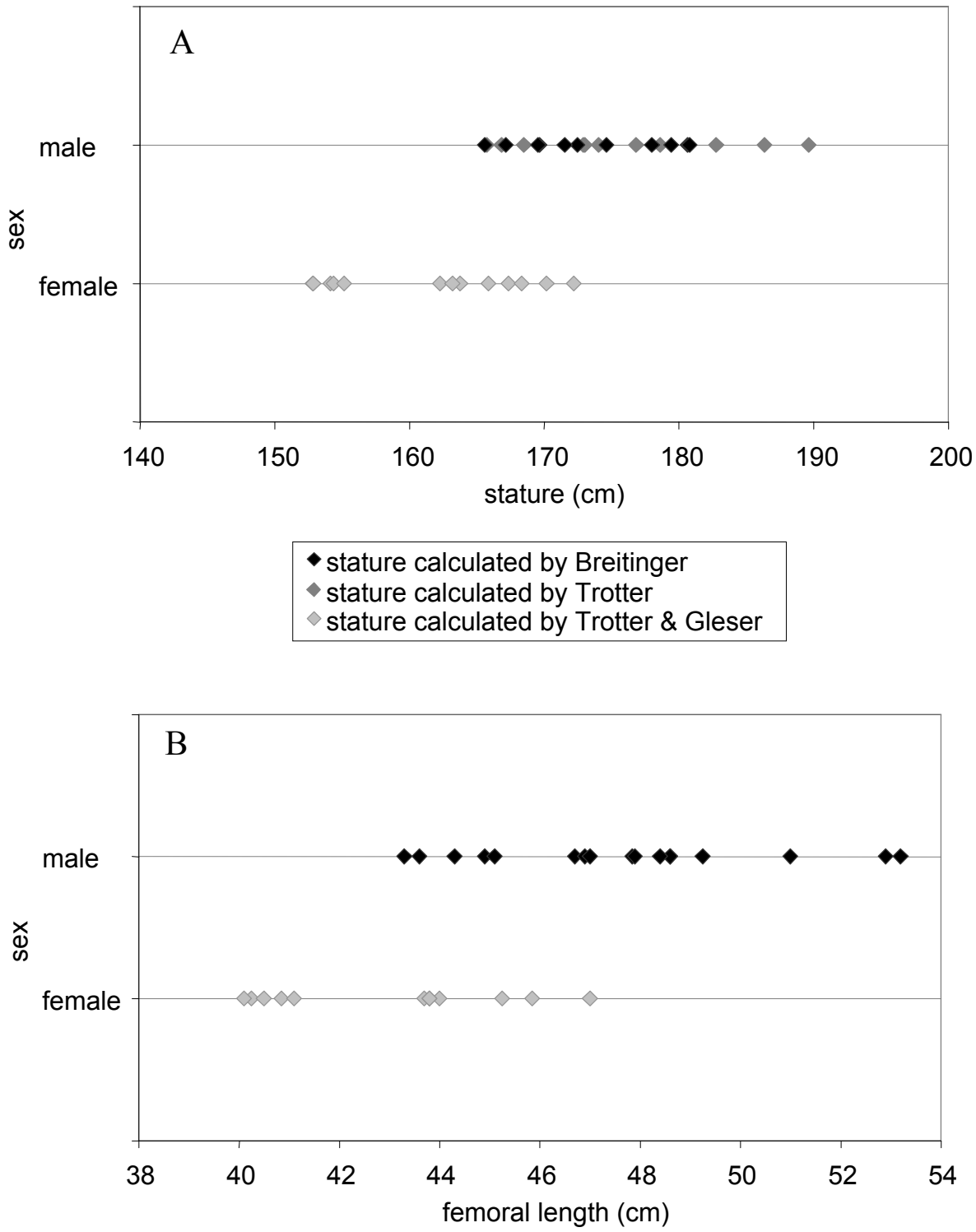


Figure 6. (A) Stature for males (calculated by Breitinger (1937) or Trotter (1970)) and for females (calculated by Trotter and Gleser (1958)). (B) Femoral length for males and females.

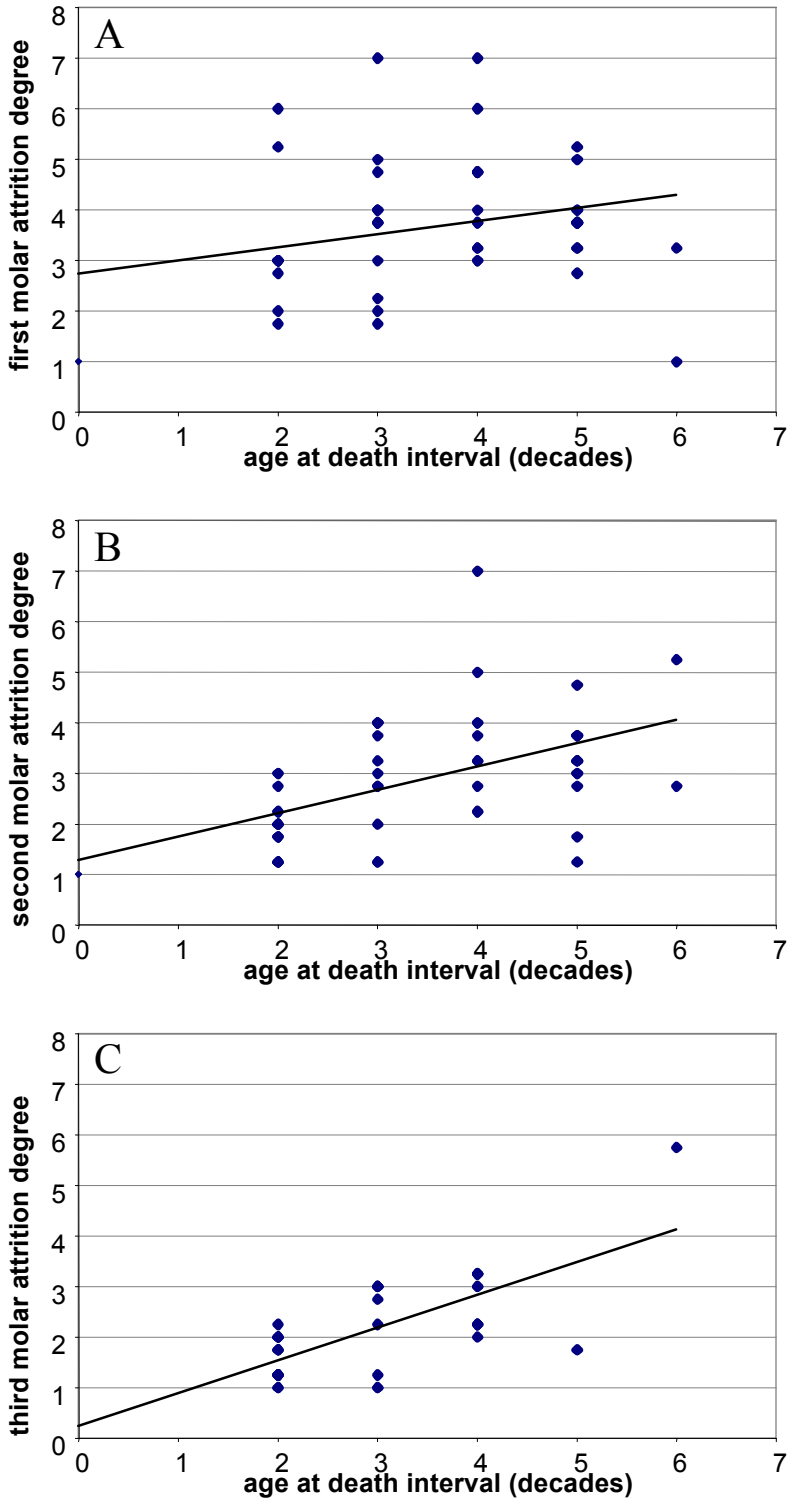


Figure 7. Degree of molar attrition for M1 (A), M2 (B) and M3 (C). Ages are categorised per decade (e.g. 2 = 20-29 years of age at death).


A


B

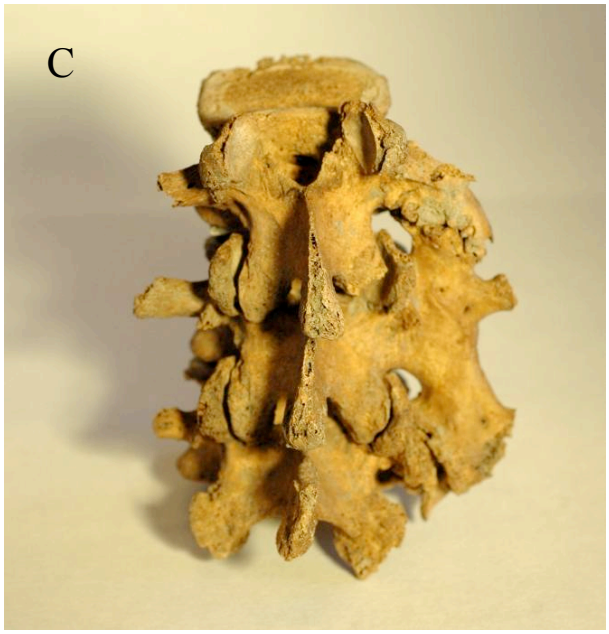
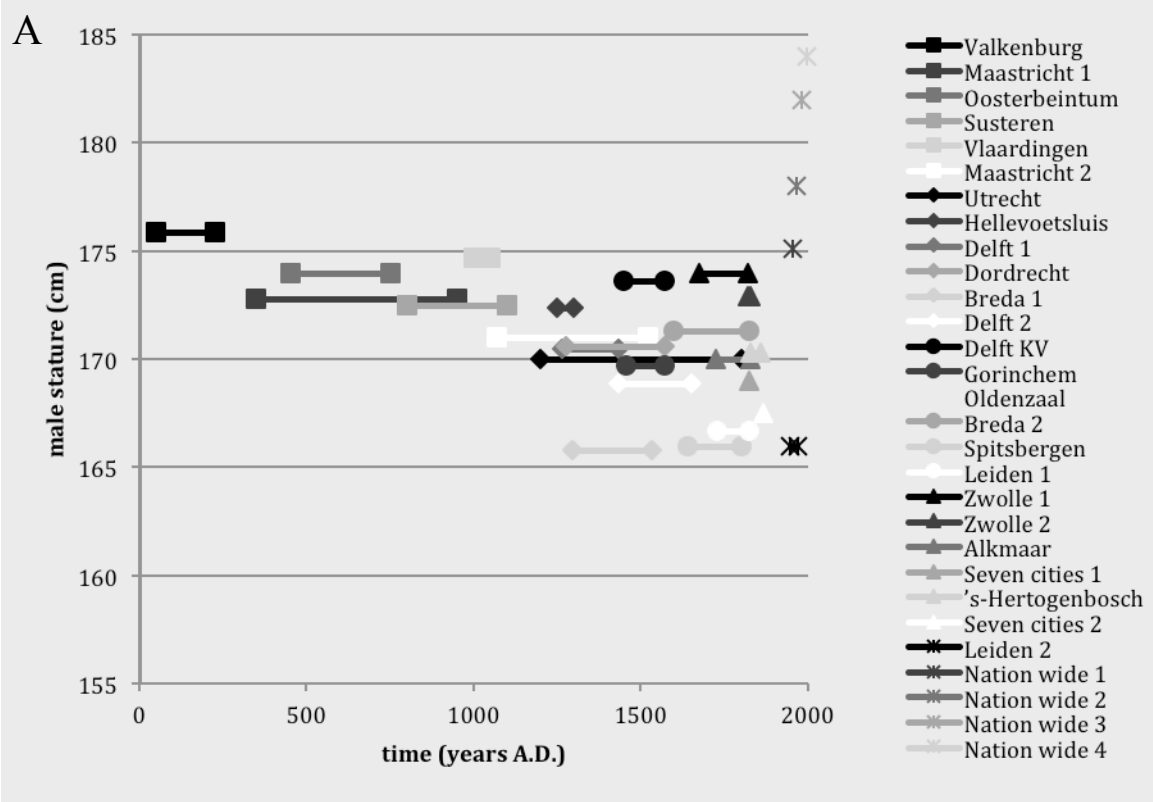

C

Figure 8. Photographs of paleaopatologies: fish vertebrae (A), asymmetrical spondylolysis (B), lumbar rib assimilation (C), coarctatio aortae (D) and an enlarged right hemisphere, from the left side of the skull (E) and from above with X-rays (F).



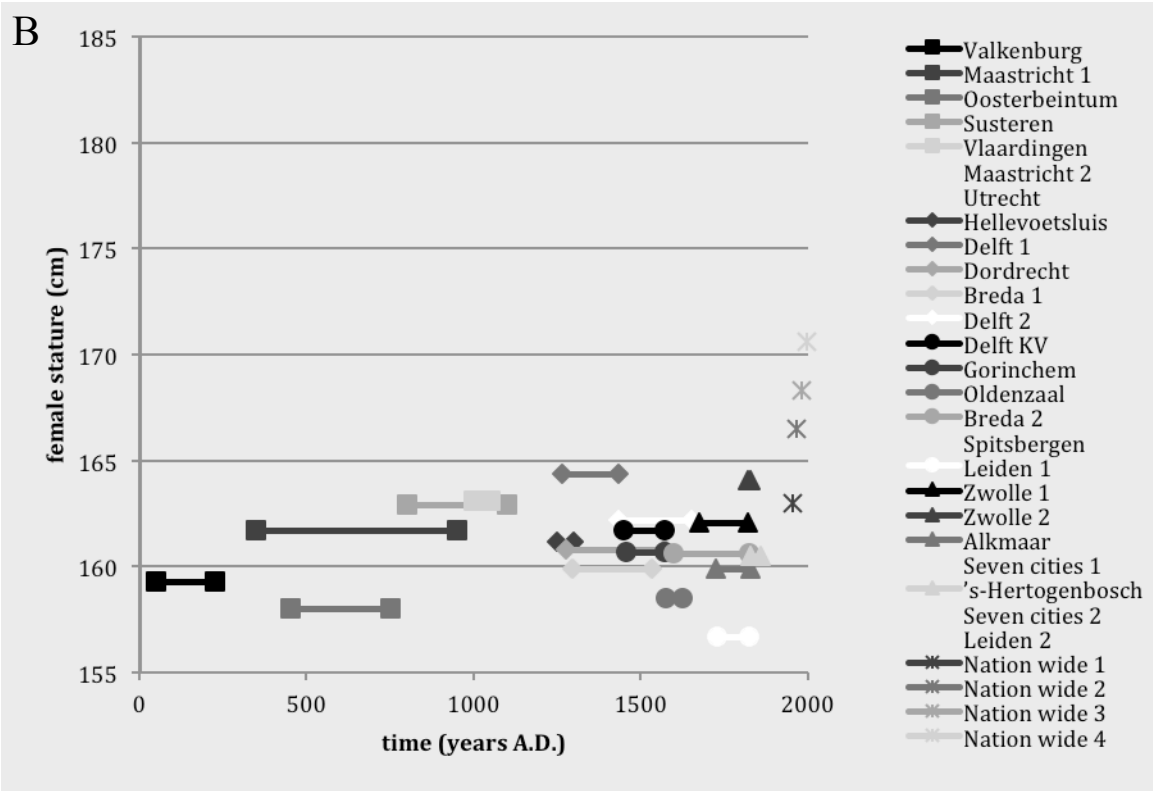
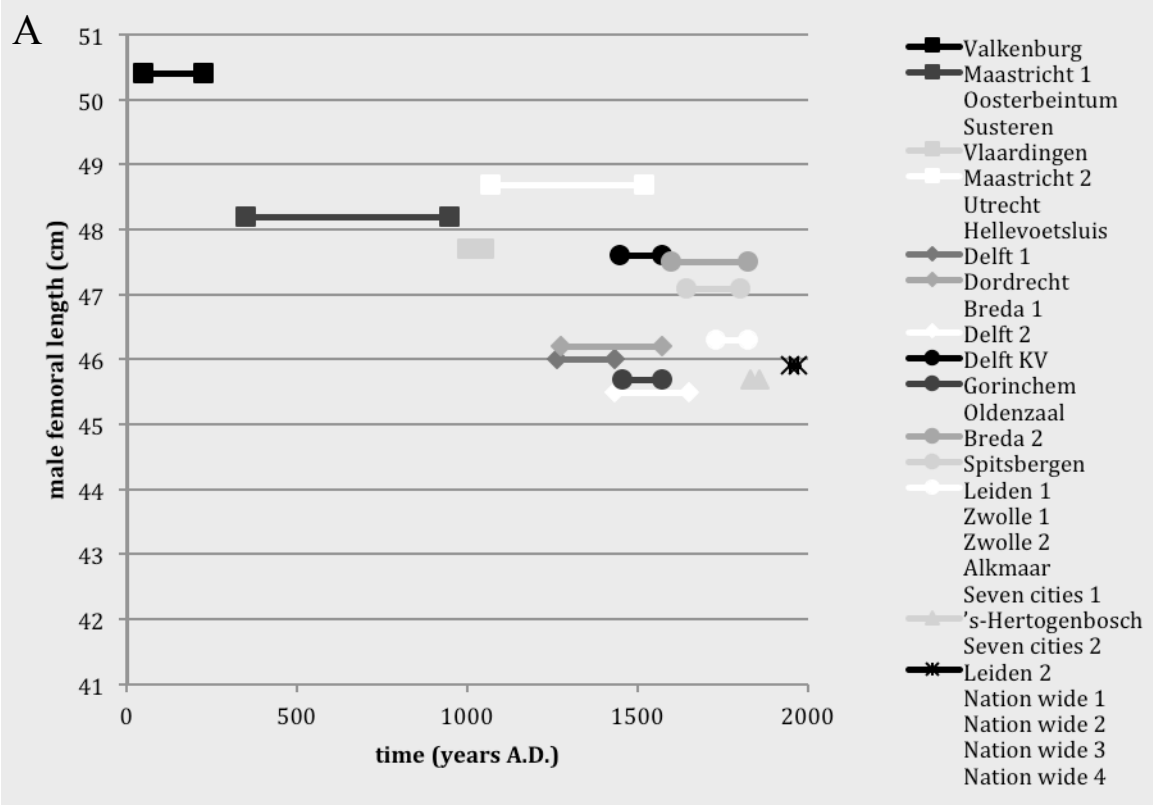


Figure 9. Average stature for males (A) and females (B). When no marker is shown in front of the legend, no data were available for this population.



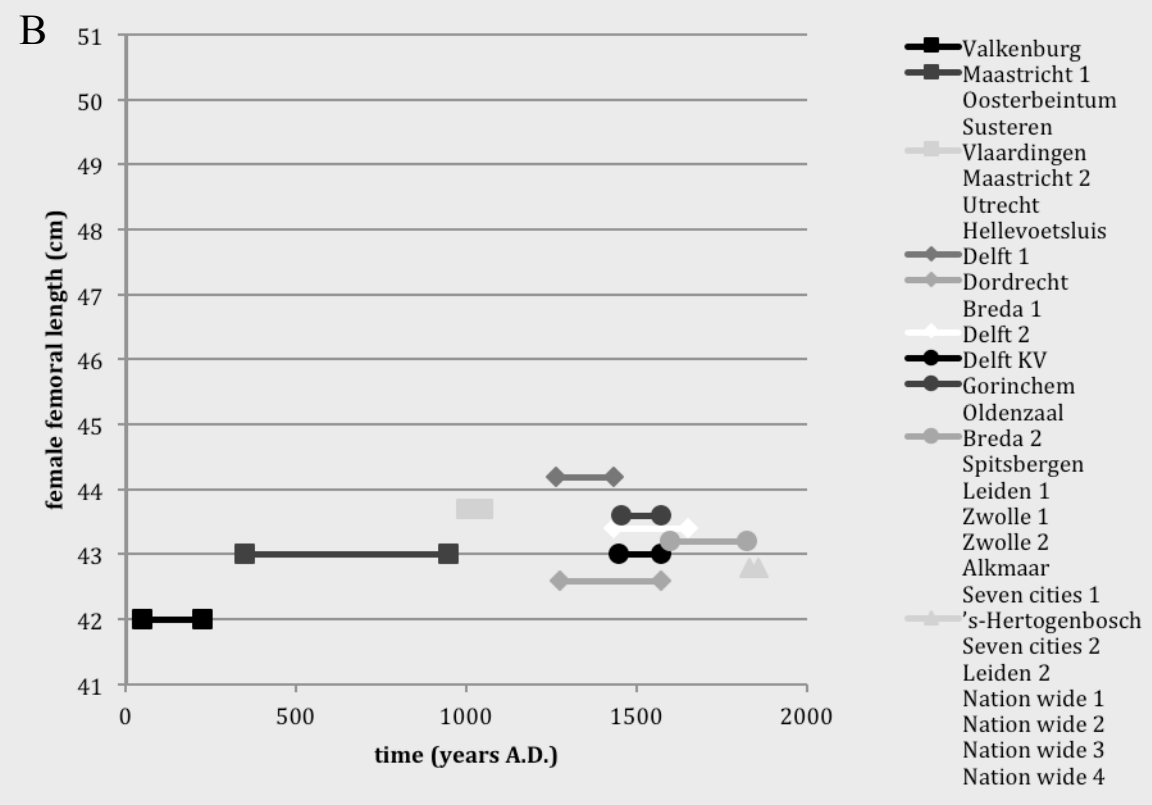


Figure 10. Average maximum femoral length for males (A) and females (B). When no marker is shown in front of the legend, no data were available for this population.

Table 1: Main demografic data per individual

find no.	pelvis[1]	pelvis[2]	caput[1]	caput[2]	sex[3]	sex[4]	age min[5]	age max[6]	age int[7]	stature T&G[8]	stature B[9]	pOA[10]	vOA[11]	DDD[12]	main pathology[13]
003	-0.25	8			f		35	55		162.29		1	1		trauma, slipped disk femur head
004	1.2	5	0.57	28	m		59.33	65.33	6	186.36	180.64	1	1	1	trauma, Poirier's facet, possible DISH
006	-1.25	12			f		35	55		170.19					rickets
007	-1.27	11	-0.33	27	f		51.67	57.67	5	165.87		1	1		rickets, possible DISH
011	-0.74	19	-0.83	30	f		32	41	3				1	1	trauma
012			-0.67	18	f		28	37	3	163.78					
013	-1	11	-0.88	8	f		46	52	4	154.14		1	1	1	periostitis, ost. dis., possible DISH
015	-0.86	14	-0.88	25	f		34	40	3	167.35		1	1	1	trauma, coarctatio aortae, ankylosis T6/7, secondary scoliosis, rickets
016a	-1	3			f		43	60				1	1	1	ankylosis C2/3
016b			-0.72	18	f			22							
019			-0.72	32	f		25	34	2			1			
022	-0.74	19			f		20	26	2	154.38			1	1	symmetrical fusion S1/L5, possible DISH
023	-1	3	-0.29	24	f	f	40	80							osteoma
028	-0.64	14	-0.21	29	f	f	19	28	2			1		1	scoliosis, sutura metopica
029	-1	14	-0.93	14	f		28.5	33.5	3						trauma, cribra femora, sinusitis maxillaris
032	0.63	8	-0.08	13	m		54.67	60.67	5						enamel hypoplasia
033	0.95	19	0.33	24	m		20	26	2	178.61	174.63	1			spina bifida occulta sacralis, cribra femora, scoliosis, rickets
034	0.6	10			m		34	43	3	166.84	167.18	1		1	Allen's fossae, possible DISH
038a			-0.56	25	f		40	80				1	1	1	periostitis, exostose humerus dextra, sutura metopica
038b	1	11			m		21	24	2	189.65	180.80	1	1	1	trauma, cribra femora, sacralisation L5 pseudo-joints, L1 extra costalis
040	-0.09	11	-1.4	5	f		55	61	5	153.84		1	1	1	trauma, fusion costalis 1/2, ankylosis T1/2, secondary scoliosis, possible DISH
041	-1.32	19	-1.13	32	f		49	55	5	155.17		1	1	1	Allen's fossae, rib rudiment assimilation L2/3/4
042					c		5	9	0						

find no.	pelvis[1]	pelvis[2]	caput[1]	caput[2]	sex[3]	sex[4]	age min[5]	age max[6]	age int[7]	stature T&G[8]	stature B[9]	pOA[10]	vOA[11]	DDD[12]	main pathology[13]
043	-1.09	11	-0.63	32	f		53.33	59.33	5	152.88		1	1	1	trauma, ost. dis., fish vertebra L4/L5, sacralisation L5, possible DISH
044	-1	10	-0.54	24	f	f	37.33	43.33	4	163.21		1	1		trauma, Allen's fossa, spina bifida L5
047	0	19	0.13	24	m	m	46.5	51.5	4	173.03	172.47	1	1	1	Allen's fossae, ost. dis., enlarged foramen incisivum
048	-0.9	10	0.11	18	f		30	36	3	168.35		1	1	1	trauma, coxygodynia
049	0.95	19	1.03	29	m		20	26	2	174.06	171.53	1		1	trauma, asymmetrical spondylolysis L5
112a	0.17	18	0	25	m		50	55	5	168.51	169.68	1	1	1	trauma, Poirier's facets, fusion 5th distal+middle phalanx, sacralisation L5 with pseudo-joints
113	-1.38	8	-0.97	32	f		40	80					1		
119	1.43	14	1.44	32	m	m	30	36	3	182.79	179.46	1	1	1	trauma, extra sacral+lumbal segment, spondylolysis L5, scoliosis, rickets
214	0.21	19	0.43	14	m	m	49	55	5	165.77	165.60	1			fusion 5th distal+middle phalanx, extra sacral segment, sutura metopica
217	-0.6	10	0.6	25	i	m	42.33	48.33	4	176.84	178.01	1	1	1	Poirier's facets, osteoma
230	-1.26	7	-0.13	32	f		40 (38)	60 (59)	4			1	1	1	trauma, enlarged R hemisphere, 5 osteomas, fibroblastoma lower jaw, secondary pOA, rickets
231	0.6	10			m		34	43	3	172.91	169.57	1	1	1	trauma, ost. dis., fusion of sacrum/ileum R., possible DISH
237	1	5	0.52	31	m		40	80				1	1	1	cribra orbitalia, exostosis tibia + femur, osteomyelitis
257	-1.1	10			f	f	50.25	55.25	5	172.21		1	1	1	trauma, cribra femora, possible DISH

1: Degree of sexualisation.
2: Weight of sex indicators.
3: Morphological sex determination (f: female, m: male, c: child, i: indifferent).
4: DNA sex determination.
5: Minimum age at death in years; between brackets when based on remodelling of subperiostal bone.
6: Maximum age at death in years; between brackets when based on remodelling of subperiostal bone.
7: Age interval (e.g. 2 = 20-29 years); when only one age indicator was available, no age interval was assigned; those with 3 or 4 indicators are underlined and their ages at death were used for calculating the average age at death.
8: Stature in cm according to Trotter and Gleser (1958) for females and Trotter (1970) for males.
9: Stature in cm according to Breitinger (1937) for males only.
10: Peripheral osteoarthritis.
11: Vertebral osteoarthritis.
12: Degenerative disk disease.
13: DISH: diffuse idiopathic skeletal hyperostosis, ost. dis.: osteochondritis dissecans, R.: right, C2: 2nd cervical vertebra, T: thoracal, L: lumbar, S: sacral.

Table 2: Dental status data

	Number of inspected individuals	Total number of Elements	Average per individual	s.d.
n erupted	32	1008	31.5	1.2
n inspected	32	495	15.5	10.8
n missing	32	261	8.2	9.4
n unerupted	32	7	0.2	0.8
n congenitally absent	32	12	0.4	1.0
n am loss	32	172	5.4	6.7
n pm loss	32	72	2.3	1.8
n supernumary	32	4	0.1	0.4
n carious	31	118	3.8	5.0
n abscesses	32	21	0.7	1.3
n fistulas	32	13	0.4	0.9

Table 3: Overview of dental status data

	Percentage
Ante-mortem loss	23.0
Post-mortem loss	12.5
Caries frequency	23.8
Abscess frequency	3.7
DM index	43.0

Table 4: Palaeopathology in adults (N=36)

Palaeopathology	n	%
Infections		
Periostitis	2	6
Osteomyelitis	1	3
Sinusitis maxillaris	1	3
Fusion of sacrum and right ileum	1	3
Cribra orbitalia	1	3
Cribra femora	3	8
Fractures		
Spondylolysis	2	6
Coxygodynia	1	3
Tumours		
Osteoma	3	8
Fibroblastoma in lower jaw	1	3
Exostose	2	6
Joint affections		
pOA	27	75
vOA	24	67
DDD	23	64
Osteochondritis dissecans	4	11
Deficiency diseases		
Rickets	6	17
Diseases "et causa ignota"		
DISH[1]	0-6	0-17
Scoliose	4	11
Slipped disk femur head	1	3
Enamel hypoplasia	1	3

1: Depending on criteria used to diagnose DISH.

Table 5: Anomalies in adults (N=36)

Anomaly	n	%
Skull		
Sutura metopica	3	8
Enlarged foramen incisivum	1	3
Enlargement right hemisphere	1	3
Axial skeleton		
Spina bifida	2	6
Sacralisation with pseudo-joints	2	6
Sacralisation	2	6
Extra sacral segment	2	6
Extra lumbal segment	1	3
Ankylosis vertebrae	3	8
Rib rudiments assimilation L2/3/4	1	3
Extra rib L1	1	3
Rib 1/2 fusion	1	3
Coarctatio aortae	1	3
Extremities		
Allen's fossa	4	11
Poirier's facet	3	8
Fusion distal+middle phalanx toe	2	6

Table 6: Tooth loss and decay for various populations from the Low Countries (after Maat, 2002a)

Cemetery	Period AD	Population	AM[1] loss (%)	Caries frequency (%)	DM(F)[2] index (%)	n	Author
Valkenburg	50-225	Native	3.6	6.5	.	30	Lonneé and Maat, 1998
Maastricht 1	350-950	Diverse	14.0	11.0	.	99	Panhuysen, 2005
Vlaardingen	1000-1050	Civilians	6.1	7.6	13.1	13	Groen and de Ridder, 2006
Maastricht 2	1070-1521	Canons	11.0	17.0	31.0	19	Janssen and Maat, 1999
Delft 1	1265-1433	Civilians	16.2	7.6	22.5	39	Onisto et al., 1998
Dordrecht	1275-1572	Civilians	12.0	12.0	26	184	Maat et al., 1998
Breda 1	1296-1535	Beguines	15.5	10.4	22.6	76	Rijpma and Maat, 2005
Delft 2	1433-1652	Civilians	19.1	12.3	30.1	30	Onisto et al., 1998
Delft KV[3]	1450-1572	Nuns	23.0	23.8	43.0	32	This study
Spitsbergen	1642-1800	Whalers	6.8	13.4	19.3	50	Maat, 1981
Alkmaar	c. 1725-1830	Civilians	.	12.2	.	107	Baetsen, 2001
Den Bosch	1830-1858	Civilians	16.5	20.7	36.2	131	Maat et al., 2002a

1: Ante-Mortem. 2: Decayed Missing (Filled). 3: Koningsveld.

Table 7: Palaeopathologies in contemporary reference populations from the Low Countries

Cemetery	Period AD	Traumata	Infections	DDD	vOA	pOA	Rickets / osteomalacia	DISH	Author
Vlaardingen[1]	1000-1050	47% (n=15)	38% (n=8)	85% (n=13)	23% (n=13)	33% (n=15)	7% (n=15)	23% (n=13)	Groen and de Ridder, 2006
Maastricht 2	1070-1521	n.a.[2]	0% (n.a.)	77% (n=17)	29% (n=17)	n.a.	4% (n=23)	100% (n=17)	Janssen and Maat, 1999
Delft 1	1265-1433	n.a.	ca. 3% (n.a.)	38% (n=50)	16% (n=50)	n.a.	2% (n=50)	8% (n=50)	Onisto et al., 1998
Dordrecht	1275-1572	ca. 22% (n=193)	ca. 4% (n=193)	64% (n=104)	28% (n=110)	n.a.	± 4% (n=192)	19% (n=150)	Maat et al., 1998
Breda 1	1296-1535	13% (n=120)[3]	3% (n=75)	28% (n=80)	23% (n=80)	n.a.	5% (n=120)	28% (n=75)	Rijpma and Maat, 2005
Delft 2	1433-1652	n.a.	ca. 10% (n.a.)	44% (n=48)	15% (n=48)	n.a.	0% (n.a.)	20% (n=46)	Onisto et al., 1998
Delft KV[4]	1450-1572	43% (n=36)	11% (n=36)	64% (n=36)	67% (n=36)	75% (n=36)	16% (n=37)	0-17% (n=35)[5]	This study
Gorinchem	1455-1572	46% (n=24)	5% (n=20)	57% (n=14)	50% (n=14)	67% (n=24)	0% (n=24)	42% (n=14)	Maat and Mastwijk, 2000

1: Percentage associated with the adult population only. 2: Data not available. 3: Spinal traumata excluded. 4: Koningsveld. 5: Depending on criteria used to diagnose DISH.

Table 8: Average age at death for various populations from the Low Countries

Cemetery	Period AD	Population	Male ≥20[1] (n)	Female ≥20[1] (n)	Overall ≥20[1] (n)	Child <20[2] (n)	Author
Maastricht 1	350-950	Diverse	43.7 (20)	35.7 (21)	39.6 (41)	(51)	Panhuysen, 2005
Oosterbeintum	450-750	Natives	.	.	± 29.5 (35)	(11)	Uytterschaut, 1996
Susteren	800-1100	Monks	± 38 (47)	± 44 (19)	.	(15)	Baetsen, 1998
Vlaardingen	1000-1050	Civilians	46.4 (9)	48.0 (6)	47.0 (15)	(26)	Groen and de Ridder, 2006
Maastricht 2	1070-1521	Canons	55.7 (24)	.	.	.	Janssen and Maat, 1999
Hellevoetsluis	1250-1300	Agricultural	± 40 (62)	± 32 (35)	± 35 (99)	(49)	Carmiggelt et al., 1999
Delft 1	1265-1433	Civilians	43 (.)	47 (.)	45 (37)	.	Onisto et al., 1998
Dordrecht	1275-1572	Civilians	.	.	44 (.)	.	Maat et al., 1998
Breda 1	1296-1535	Beguines	43.3 (9)	43.0 (49)	43.2 (58)	(7)	Rijpma and Maat, 2005
Delft 2	1433-1652	Civilians	43 (.)	49 (.)	46 (32)	.	Onisto et al., 1998
Delft KV[3]	1450-1572	Men/nuns	42.0 (10)	44.3 (11)	43.2 (21)	(1)	This study
Gorinchem	1455-1572	Civilians	53.3 (12)	50.6 (9)	52.1 (21)	.	Maat and Mastwijk, 2000
Oldenzaal	1575-1625	Nuns	.	40.9 (5)	.	.	Baetsen,1999
Breda 2	1600-1824	Civilians	47.8 (18)	51.8 (20)	49.7 (38)	.	Maat and Mastwijk, 2000
Zwolle	1819-1828	Civilians[4]	.	.	± 50 (141)	.	Aten, 1992
Alkmaar 1	c. 1725-1830	Civilians[4]	60.1 (69)	56.2 (82)	.	.	Baetsen, 2001
Alkmaar 2	c. 1725-1830	Civilians[5]	60.3 (87)	55 (101)	.	(55)	Baetsen, 2001
Den Bosch	1830-1858	Civilians	43.4 (83)	41.4 (74)	42.2 (161)	(68)	Maat et al., 2002a

1: Age at death ≥ 20 years of age. 2: Age at death < 20 years of age. 3: Koningsveld. 4: Identified persons.
5: Unidentified persons.

Table 9: Average stature for adults for various populations from the Low Countries

			Males				Females				
Cemetery	**Period AD**	**Population**	**Stature[1]**	**s.d.[2]**	**n**	**Method**	**Stature[1]**	**s.d.[2]**	**n**	**Method**	**Author**
Valkenburg	50-225	Native	175.9	.	10	Trotter[3]	159.3	.	2	T&G[4]	Lonneé and Maat, 1998
Maastricht 1	350-950	Diverse	172.8	4.6	43	Breitinger[5]	161.7	6.9	53	T&G	Panhuysen, 2005
Oosterbeintum	450-750	Civilians	174.0	.	7	Trotter	158.0	.	9	T&G	Uytterschaut, 1996
Susteren	800-1100	Monks/nuns	172.5	.	13	Breitinger	162.9	.	30	T&G	Baetsen, 1998
Vlaardingen	1000-1050	Civilians	174.7	5.0	7	Breitinger	163.1	3.6	6	T&G	Groen and de Ridder, 2006
Maastricht 2	1070-1521	Canons	171.0	4.0	23	Breitinger					Janssen and Maat, 1999
Utrecht	1200-1800	Johannites	170.0	.	61	Trotter					Pot and de Groot, 1989
Hellevoetsluis	1250-1300	Agricultural	172.4	6.2	55	Trotter	161.2	4.5	33	T&G	Carmiggelt et al., 1999
Delft 1	1265-1433	Civilians	170.5	4.6	25	Breitinger	164.4	7.8	14	T&G	Onisto et al., 1998
Dordrecht	1275-1572	Civilians	170.6	3.8	80	Breitinger	160.8	6.1	80	T&G	Maat et al., 1998
Breda 1	1296-1535	Beguines	165.8	5.8	8	Trotter	159.9	4.5	55	T&G	Rijpma and Maat, 2005
Delft 2	1433-1652	Civilians	168.9	3.4	19	Breitinger	162.2	7.1	20	T&G	Onisto et al., 1998
Delft KV[6]	1450-1572	Men, nuns	173.6	5.0	11	Breitinger	161.8	3.8	13	T&G	This study
Gorinchem	1455-1572	Civilians	169.7	.	11	Breitinger	160.7	.	11	T&G	Maat and Mastwijk, 2000
Oldenzaal	1575-1625	Nuns					158.5	.	7	T&G	Baetsen,1999
Breda 2	1600-1824	Civilians	171.3	.	19	Breitinger	160.6	..	23	T&G	Maat and Mastwijk, 2000
Spitsbergen	1642-1800	Whalers	166.0	6.9	41	In situ[7]					Maat, 1981
Leiden 1	1730-1825	Civilians	166.7	9.3	49	In situ	156.7	9.3	.	In situ	Maat et al., 1984
Zwolle 1	c. 1675-1819	Civilians[8]	174.0	.	69	Trotter	162.1	.	70	T&G	Aten, 1992
Zwolle 2	1819-1828	Civilians[9]	172.9	.	33	Trotter	164.1	.	37	T&G	Aten, 1992
Alkmaar 1 en 2	c. 1725-1830	Civilians	170.0	.	.	Breitinger	159.9	.	76	T&G	Baetsen, 2001
Seven cities 1	1825	Soldiers	169.0	.	382	Living[10]					Oppers, 1966
Den Bosch	1830-1858	Civilians	170.3	6.5	82	Breitinger	160.5	6.3	84	T&G	Maat et al., 2002a
Seven cities 2	1865	Soldiers	167.5	.	722	Living					Oppers, 1966
Leiden 2	1947-1970	Civilians	166.0	7.9	86	Cadaver					Maat, 2001
Nationwide 1	1955	Civilians	175.1	.	.	Living	163.0	.	.	Living	de Wijn and de Haas, 1960
Nationwide 2	1965	Civilians	178.0	.	.	Living	166.5	.	.	Living	van Wieringen et al., 1971
Nationwide 3	1980	Civilians	182.0	.	.	Living	168.3	.	.	Living	Roede, 1985
Nationwide 4	1997	Civilians	184.0	.	.	Living	170.6	.	.	Living	Fredriks et al., 2000

1: Stature in cm. 2: Standard deviation. 3: Trotter, 1970. 4: Trotter & Gleser, 1958. 5: Breitinger, 1937. 6: Koningsveld.
7: Measured articulated in situ. 8: Unidentified persons. 9: Identified persons. 10: Living standing height.

Table 10: Average maximum femoral length for adults for various populations from the Low Countries

			Males			Females			
Cemetery	**Period AD**	**Population**	**MaxFem**[1]	**s.d.**[2]	**n**	**MaxFem**[1]	**s.d.**[2]	**n**	**Author**
Valkenburg	50-225	Native	50.4	1.5	3	42.0	.	2	Lonneé and Maat, 1998
Maastricht 1	350-950	Diverse	48.2	2.8	29	43.0	2.9	36	Panhuysen, 2005
Vlaardingen	1000-1050	Civilians	47.7	2.6	6	43.7	2.2	6	Groen and de Ridder, 2006
Maastricht 2	1070-1521	Canons	48.7	2.0	17				Janssen and Maat, 1999
Delft 1	1265-1433	Civilians	46.0	2.6	20	44.2	.	14	Onisto et al., 1998
Dordrecht	1275-1572	Civilians	46.2	2.5	59	42.6	2.1	54	Maat et al., 1998
Delft 2	1433-1652	Civilians	45.5	1.9	16	43.4	.	20	Onisto et al., 1998
Delft KV[3]	1450-1572	Men/nuns	47.6	2.9	17	43.0	2.4	12	This study
Gorinchem	1455-1572	Civilians	45.7	2.6	11	43.6	.	10	Maat and Mastwijk, 2000
Breda 2	1600-1824	Civilians	47.5	2.6	14	43.2	.	14	Maat and Mastwijk, 2000
Spitsbergen	1642-1800	Whalers	47.1	3.0	38				Maat, 1981
Leiden 1	1730-1825	Civilians	46.3	2.3	12				Maat et al., 1984
Den Bosch	1830-1858	Civilians	45.7	2.5	67	42.8	2.5	53	Maat et al., 2002a
Leiden 2	1947-1970	Civilians	45.9	2.7	100				Maat, 2001

1: Average maximum femoral length in cm. 2: Standard deviation. 3: Koningsveld.