Life in transition : an osteoarchaeological perspective of the consequences of mediëval socioeconomic developments in Holland and Zeeland (AD 1000-1600)

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6

Discussion

6.1 INTRODUCTION

The primary objective of this research was to study the consequences of socioeconomic developments during the medieval period in Holland and Zeeland using an osteoarchaeological approach. As discussed in chapter one, historical literature can give information on general trends and developments such as broad changes in subsistence patterns, environmental circumstances, and living conditions. However, how these changes influenced people at an individual physical level is difficult to assess using exclusively historical data. The analysis of human skeletal remains from different archaeological sites provides a new, uniquely direct, perspective on the impact of socioeconomic developments on urban and rural populations of the Middle Ages.

This study has demonstrated that medieval socioeconomic developments had physical consequences for the citizens of Holland and Zeeland. Although not all aspects of medieval life are reflected in the human remains, the comparison of early rural Blokhuizen with later rural Klaaskinderkerke and urban Alkmaar has shown differences as well as similarities between the prevalence and expression of skeletal indicators of disease, activity, and diet. Several of the observed patterns could be related to the medieval socioeconomic changes, thereby improving our understanding of the physical impact of these developments for the people.

While there are small differences between the rural and urban collections, one of the main findings of this research is the absence of a clear-cut division between the two living environments in terms of disease, activity, and diet. Not surprisingly, the lives of the medieval citizens seem to have been influenced by many factors, with living environment perhaps being a smaller aspect than previously assumed. Based on the skeletal data, there is no marked rural-urban divide in medieval Holland and Zeeland, in contrast to data from other places in medieval Europe (Woods 2003). The negative association between health and urban living ingrained in our perception of past societies is not supported by this research.

This chapter discusses the results of the osteoarchaeological analyses in relation to the historical contextual information. This discussion demonstrates the importance of local research into physical consequences of medieval socioeconomic changes on the lives of rural and urban people.

6.2 DISEASE AND MEDIEVAL DEVELOPMENTS

An important objective of this research was to assess if late medieval socioeconomic developments influenced disease patterns and general stress levels. This was done through comparison of the prevalence of certain infectious diseases and indicators of non-specific stress among three skeletal assemblages: Blokhuizen, Klaaskinderkerke, and Alkmaar

6.2.1 Rural comparisons

Specific infections: respiratory diseases

Skeletal lesions associated with specific infectious diseases were not encountered in the rural skeletal collection of Blokhuizen. It has to be noted that the poor preservation of the Blokhuizen remains could have influenced the results: only 28% of individuals had a thorax available for inspection. However, air-borne infections, which include lung diseases such as tuberculosis, are likely to have been less common in areas with more fresh air and less crowded living conditions. Considering that the inhabitants of Blokhuizen would likely have lived in small dispersed farm houses, the absence of signs of these types of infections falls within expectations. Similarly, no evidence of respiratory infections was encountered in the comparative rural skeletal collection of Vronen (Alders and van der Linde 2011). Interestingly, however, data from England present a different image. The skeletal remains from Raunds Furnells, a rural settlement in England (AD 850–1100), showed indications of a possible tuberculosis infection, although only one individual appears to have been affected (Powell 1996). Lewis (1999) also notes that respiratory infections were common in the rural skeletons she analysed. Additionally, Mays and colleagues (2001) encountered *M. tuberculosis* in several individuals from the rural village of Wharram Percy, England (AD 950-1500). Using ancient DNA research, they confirmed that the individuals were affected by the human (and not bovine) form of tuberculosis. Considering that the population density in Wharram Percy was probably low, Mays *et al.* (2001) link the occurrence of the disease to contact with the urban centre of York. Several larger towns already existed in England during the central medieval period. Although incidental interaction with more distant towns cannot be ruled out, the potential exposure to tuberculosis for the inhabitants of Blokhuizen and Vronen was limited considering the fact that there were no urban centres in Holland during the central medieval period.

The second rural collection, from Klaaskinderkerke, did not provide definitive cases of infectious disease. There is only one individual who showed new bone formation on the visceral surface of the ribs which suggests a chronic lung infection. Similarly, in the contemporary rural skeletal collection from Cruyskerke, no evidence of specific infections or chronic lung diseases was encountered (Sannen 2010). This indicates that there is no discernible increase in the prevalence of these types of diseases in the later rural settlements in comparison with the earlier ones such as Blokhuizen and Vronen. Even though population size increased in Holland and Zeeland in this period, population densities in rural villages appear to have remained too low to sustain crowd-dependent diseases such as tuberculosis.

An important change from the central to late medieval period in Holland and Zeeland was increased contact with more densely populated areas. As discussed in chapter one, many urban centres came into existence during this period. This, in combination with greater market dependence, would have increased interaction and contact between the rural areas and towns. This could have promoted the spread of air-borne diseases to the rural hinterland, as appears to have been the case for the individuals in Wharram Percy (Mays *et al.* 2001). Klaaskinderkerke, and especially Cruyskerke, are close to urban centres such as Dordrecht and Zierikzee, which had relatively high population densities in this period. The absence of skeletal lesions suggest that the assumed increased contact with nearby towns did not result in a higher prevalence of respiratory infections in Klaaskinderkerke and Cruyskerke which could indicate that these types of diseases were absent in the towns the rural inhabitants were in contact with. However, considering the fact that diseases like tuberculosis need a relatively high population density to sustain themselves, the limited population size and density in rural villages likely resulted in rapid dissolution of bacteria (Dobson and Carper 1996; Mays *et al.* 2001). Lewis (1999, 2002) came to similar conclusions in her research, when studying the process of urbanisation and industrialisation by comparing the non-adults of different English sites. She found no significant differences in the prevalence of infectious diseases between the early and later medieval rural non-adults. Even though her focus on non-adults may have resulted in different patterns, Lewis' data concur with the results from the present research, indicating that the socioeconomic developments in the late medieval period did not visibly impact the prevalence of certain infectious diseases in the countryside.

Specific infections: animal-borne diseases

While the human form of tuberculosis is unlikely to have been present in the early rural settlements, the bovine form is likely to have been common in Holland in the central medieval period given the expected regular contact with cattle. Although it is not possible to distinguish between the two types of tuberculosis on the basis of skeletal remains, the absence of characteristic lesions for either form in Blokhuizen and Vronen (Alders and van der Linde 2011) suggests that the *M. bovis* was not present in the villages. Other specific animal-

borne diseases such as brucellosis were also not encountered in the skeletal remains from Blokhuizen and Vronen. The absence of skeletal lesions associated with bovine tuberculosis and brucellosis suggests that these diseases were uncommon in the countryside in the period between AD 1000 and 1200. Similar results were obtained in English research: in addition to human bone samples, Mays and colleagues (2001) tested some bovine remains from the site of Wharram Percy for the presence of *M. bovis* and found no evidence for the disease, even though the authors expected this disease to have been common. Moreover, the scholars were unable to find the *Brucella* bacteria in any of the analysed humans (Mays *et al.* 2001). The absence of skeletal evidence and negative DNA results suggest that animal diseases were of lesser importance in the medieval period than previously assumed.

While there is no direct evidence for specific animal diseases, close contact with animals could have resulted in several other afflictions. The use of faeces as fertilisers exposed villagers to parasites such as roundworms and hookworms (Lewis 1999), which may have resulted in anaemia. Microscopic analyses of samples from cesspits used in medieval towns indeed indicate the occurrence of intestinal parasites. Research on material from the late medieval Dutch city of Kampen demonstrated the presence of roundworms and whipworms (Haaster *et al.* 2000). Anthrax, another virulent bacterial infection, was most likely also a common disease in the medieval period for people working with animals on a regular basis. In addition to being fatal for livestock, humans can become infected with this disease by touching the hides of the affected animals, resulting in a characteristic black lesion on the skin, or by eating meat contaminated with the bacterium (Sternbach 2003; Lewis 1999). Archaeological and historical evidence suggest that these diseases and parasitic infections played an important role in medieval society. However, as they do not result in specific skeletal lesions, their prevalence cannot be directly studied from an osteoarchaeological perspective. Nonetheless, these animal related afflictions may have been responsible for non-specific stress markers, which are addressed below.

The comparison of the early rural skeletal assemblages with later medieval ones demonstrated no osteoarchaeologically visible increase in animal-borne infections. No indications for brucellosis or bovine tuberculosis have been found in the human skeletal remains from Klaaskinderkerke. Even though pastoral farming was less common in Zeeland in comparison with Holland (van Steensel 2012b), the inhabitants of Klaaskinderkerke would have owned animals for private use. Taking into account that animals and humans presumably lived in the same dwelling, diseases such as brucellosis or bovine tuberculosis could have been common in the late medieval period as well. DNA evidence from a pit with cattle remains dating to the late medieval period has shown that brucellosis was present in The Netherlands in late medieval times (de Jong and Houwers 2008), but the extent of the disease is currently unknown. It is possible that the prevalence of bovine tuberculosis and brucellosis are grossly underestimated in the archaeological record due to the limited skeletal involvement of both

diseases (Waldron 2009). However, the skeletal absence of specific animal diseases in both Dutch and English rural skeletal collections points to a low significance of these infections in the medieval period.

Non-specific stress markers

To investigate the presence of other diseases or deficiencies which do not leave any specific lesions in the skeleton, non-specific skeletal stress markers were studied. Stunting of growth is considered to be an important indicator of childhood stress, even though catch-up growth could obscure some differences (Goodman and Armelagos 1989). Average adult stature for males is 172 cm in the Blokhuizen collection. This is equal to the average stature of the males from Vronen (Alders and van der Linde 2011). In Blokhuizen, the females had an average height of 164 cm. This is only slightly shorter than in Vronen, where the females had an average stature of 165 cm (Alders and van der Linde 2011). Even though only a small number of individuals from both sites could be assessed, the average stature for males from Blokhuizen and Vronen is comparable with the average height of other skeletal collections from the same time period (Maat 2005; Steckel 2004). Table 6.1 displays the male stature trend in northern Europe based on skeletal collections from Scandinavia, The Netherlands, and Britain through time. The average stature for the central medieval period is 173.4 cm, which is only slightly higher than what was found for the Blokhuizen and Vronen males.

The table shows that stature decreased through time, mainly in the post-medieval period, most likely as a result of processes associated with industrialisation. However, some loss of height is also apparent from central to late medieval times. This slight trend is, however, not reflected in the skeletal remains in the present study. Mean stature of the males and females in Klaaskinderkerke is 174 cm and 164 cm, respectively. Statistically, the average Klaaskinderkerke statures do not differ significantly from those of Blokhuizen. The lack of difference between the stature means of both males and females suggests that stress levels did not markedly increase (or decrease) in the countryside as a result of socioeconomic developments in the late medieval period.

Table 6.1: Adult male stature trends in northern Europe (after Steckel 2004, table 2, p. 216).

Time period	Average stature (cm)
9th–11th centuries	173.4
12th–14th centuries	171.5
17th–18th centuries	167.5
18th century	166.2
Late 19th century	169.7

The comparison of the other non-specific skeletal stress markers gave similar results. In Blokhuizen, 53% of the sample had enamel hypoplasia and in Klaaskinderkerke 54% of studied individuals were affected. Unfortunately, the enamel hypoplasia prevalence is difficult

to compare with Cruyskerke and Vronen, as different methods were used. Considering that there were no statistically significant differences in the number of teeth for each tooth type between Blokhuizen and Klaaskinderkerke, the lack of difference in enamel hypoplasia prevalence suggests that stress remained at a similar level through time. The data on enamel hypoplasia are preferred over stature data since the former is a permanent marker while growth stunting as a result of childhood stress can be obscured in adult height due to catch-up-growth. Enamel hypoplasia prevalence can be lost due to dental wear, which was addressed by excluding old adults from the sample. Given the lack of significant differences between the sites with regards to age, this should have been of minimal effect in this research. Therefore, the lack of difference in enamel hypoplasia prevalence between Blokhuizen and Klaaskinderkerke is a strong indication of the lack of difference in non-adult stress.

The same trends can be observed through the comparison of the prevalence of cribra orbitalia. Cribra orbitalia (in active and healed states) was found in 23.2% of the Blokhuizen individuals. As expected based on the differences in the location of red blood cell production (Walker *et al.* 2009), more non-adults than adults were affected by cribra orbitalia (53.3% of the non-adults and only 12.2% of the adults). The orbital lesions were found in 25.9% of the Klaaskinderkerke individuals, all of whom were adults. In comparison with Blokhuizen, the Klaaskinderkerke prevalence is very comparable.

Conservative comparisons with the comparative sites, bearing in mind methodological issues, demonstrate differences in prevalence of cribra orbitalia, with Blokhuizen and Klaaskinderkerke having higher rates. In Vronen and Cruyskerke, only 16.6% and 1.9%, respectively, of individuals are reported to have been affected by cribra orbitalia. Although this may suggest that general stress was higher in Blokhuizen and Klaaskinderkerke, considering that there were no differences in average height, a different explanation is more likely. The occurrence of endemic malaria in the area around Blokhuizen and Klaaskinderkerke may have been responsible for the high prevalence of cribra orbitalia. As discussed in chapter three, malaria can cause chronic anaemia in turn often causing cribra orbitalia (Gowland and Western 2012). Considering the fact that both Blokhuizen and Klaaskinderkerke were located in areas with numerous marshes (Schats 2015b), the endemic presence of malaria mosquitoes could be a major factor contributing to the high prevalence of cribra orbitalia. Cruyskerke appears to have been in an area with low malaria endemicity (Schats 2015b), possibly explaining its very low cribra orbitalia prevalence. Vronen, located in a region where malaria mosquitoes were common, the cribra orbitalia prevalence is higher than in Cruyskerke. An explanantion for the difference between Blokhuizen and Vronen was that the latter was not located on peat, but on geest lands (soils composed of mixture of peat, clay, and sand from sand dunes which are slightly elevated in the landscape). Although the area surrounding the village would have still been relatively wet, the slight elevation may

have resulted in a drier area directly surrounding Vronen which was less suited for malaria mosquitoes hence causing a lower cribra orbitalia prevalence.

In summary, the inter-site comparisons for each non-specific stress marker gave similar results: there are no statistically significant differences between central medieval rural Blokhuizen and late medieval rural Klaaskinderkerke, suggesting no marked increase or decrease in stress levels. Similar results have been found in other studies. Lewis (1999, 2002) also found no differences in stress markers between early and later medieval rural non-adults. It is important to note that the comparison of non-specific stress markers cannot reveal if the source(s) of stress changed. However, the lack of difference indicates that even though socioeconomic circumstances changed as a result of medieval developments, this did not result in a major increase or decrease of general stress levels.

Changes in life ≠ changes in disease

As discussed in the chapter one, the socioeconomic developments in the late medieval period influenced several aspects of rural life. Changes in agricultural practices, shifts in occupation, interaction with urban centres, and the reduction of self-sufficiency all impacted the rural residents. Yet, the lack of difference in prevalence of infectious disease and non-specific stress markers between Blokhuizen and Klaaskinderkerke and the other contemporary rural collections suggests that these changes did not visibly impact disease frequency. These results suggest that the individuals of Blokhuizen and Klaaskinderkerke were able to adequately adapt to changes in socioeconomic circumstances.

6.2.2 Rural-urban comparisons

Specific infections: respiratory diseases

The urban skeletal remains do show a change in disease patterns: tuberculosis and other signs of chronic lung disease were only encountered in Alkmaar, indicating that the transformation to urban living indeed impacted infectious disease prevalence. The Alkmaar collection yielded two individuals with skeletal lesions pathognomonic for tuberculosis: clear spinal lytic lesions and collapse of the vertebral column. In addition, three individuals displayed the characteristic lesions on the visceral surface of the ribs associated with a chronic respiratory infection, possibly also tuberculosis.

The fact that tuberculosis, infamous as a disease of overcrowding and poor living, is found in Alkmaar and not in any of the rural sites suggests that living in the urban environment had an effect on infectious disease prevalence. The higher population density in comparison with the rural areas may have been responsible for this. However, there are other Dutch urban skeletal collections from the same time period which do not show evidence for this disease.

In the skeletal remains from the Franciscan friary in Dordrecht (Maat *et al.* 1998) and in the collection from Koningsveld in Delft (Groen, forthcoming), both towns with higher population densities than Alkmaar, tuberculosis or other lung diseases are not encountered. This may suggest that not all urban centres were plagued by the same diseases. Most likely, this is the result of local differences in living conditions and hygienic measures. Additionally, the presence of infirmaries with their own graveyard could have influenced the data: diseased individuals would be buried there and not in the regular cemeteries. In Alkmaar, however, even though infirmaries were present in the late medieval period (Vis 1991, 2007), none had their own cemeteries. People who died in the infirmaries were buried in one of the Alkmaar regular cemeteries (Bitter 2015, pers. comm.). This is also shown by the list of individuals buried at the Franciscan friary (appendix 1): for example, Anna Jansdochter appears to have come from the infirmary, as it is noted in the archival sources as '*uittet gasthuis*' meaning 'from the infirmary'.

To date, there are no known rural skeletal collections from Holland and Zeeland with osteological indications of tuberculosis, pointing to the more urban profile of this disease. In contrast to this, Lewis (1999, 2002), found a higher prevalence of respiratory disease in the rural compared to the urban skeletons she studied. Lewis relates this higher prevalence to allergic reactions as a result of close contacts with animals and exposure to soil pollutants (Lewis 1999, 2002). While the villagers in the countryside of Holland and Zeeland could have been exposed to similar pollutants, this appears not to have been sufficiently chronic or severe to cause a visible impact on the skeleton.

Specific infections: animal-borne diseases

As in the rural collections of Blokhuizen and Klaaskinderkerke, no confirmed cases of specific infections transmitted by animals were found in the Alkmaar collection. There are no skeletal signs of brucellosis. Similarly, in Delft and Dordrecht, no specific animal diseases were encountered in the skeletons. It is, however, possible that the individuals diagnosed with tuberculosis in Alkmaar could in fact have been suffering from the bovine instead of the human form. Since the skeletal consequences of the two diseases is the same (Mays *et al.* 2001; Waldron 2009), it is not possible to distinguish *M. bovis* from *M. tuberculosis* on the basis of osteological criteria alone; ancient DNA testing would be necessary. However, as was argued by Mays and colleagues (2001), it is expected that the human form of tuberculosis is more common in urban environments considering the more densely populated living conditions. Moreover, the majority of the urban population of Alkmaar probably had less direct contact with animals. Yet, it has to be noted that infection through the ingestion of contaminated cattle products, primarily milk, would have been a risk for both rural and urban residents. However, this would most likely have resulted in a primary lesion in the alimentary tract or cervical lymph nodes (Aufderheide and Rodríguez-Martín 1998; Mays

et al. 2001), and is therefore less likely to result in the spinal deformities associated with tuberculosis such as observed in Alkmaar.

Non-specific stress markers

While specific infectious diseases are only observed in the Alkmaar collection, the non-specific stress markers did not increase in comparison with Klaaskinderkerke and Blokhuizen. Average male stature is 175 cm and average female stature is 162 cm in Alkmaar. These average male and female statures are comparable to those of Blokhuizen (M=172 cm and F=164 cm) and the Klaaskinderkerke skeletons (M=174 cm and F=164 cm); the observed differences are not statistically significant. These stature means are also comparable to the average stature of the individuals in the Koningsveld collection (Delft) (M=176 cm and F=162 cm) (Groen, forthcoming) and in the Dordrecht collection (M=173 cm and F=161 cm) (Maat *et al.* 1998), indicating only minor differences between the urban centres in the county of Holland. The fact that there are only slight variations in stature means between the rural and urban skeletal collections suggest that stress levels did not markedly change as a result of the socioeconomic developments.

A similar trend is demonstrated by the comparison of enamel hypoplasia prevalence. While there were slightly more individuals with enamel defects in the Alkmaar collection (65.3%) than in Blokhuizen (52.9%) and Klaaskinderkerke (53.8%), the number of affected individuals in the urban collection is not significantly higher than at the rural sites. There are some differences in the types of teeth that were available for study between the collections, but considering that the sample includes only individuals with three or more anterior teeth and no old adults, this should not have influenced the results to any great extent. Therefore, the lack of difference in enamel hypoplasia prevalence between the three skeletal populations is a clear indication of an absence of differences in childhood stress.

Comparing the prevalence of cribra orbitalia between the three collections reveals slightly higher rates of this stress marker in the rural settlements. Both Blokhuizen and Klaaskinderkerke have a higher percentage of individuals affected (23.2% and 25.9%, respectively) while in Alkmaar 18.1% of individuals were affected. These differences between the sites do not reach statistical significance. In comparison with the Dordrecht skeletons, the prevalence of cribra orbitalia in Alkmaar is high: in Dordrecht only three percent of the individuals had the orbital lesions (Maat *et al.* 1998). The fact that the prevalence of cribra orbitalia is high in the collections from the present study can be explained by the possible malaria endemicity in the areas surrounding the studied sites. Both Holland and Zeeland were favoured by malaria mosquitoes due to the presence of brackish water. Dordrecht, although in the county of Holland, is considered to be an area with less malaria mosquitoes, at least in the post-medieval period (Schats 2015b; Seventer 1969).

If malaria was indeed responsible for at least some of the observed cribra orbitalia, the small differences between the urban and rural environments may be explained by the fact that malaria mosquitoes were most likely more prevalent in the countryside. Modern research suggests that urban environments are typically less suitable for malaria mosquito vectors (Brieger 2011; Hay *et al.* 2005) which may have been the case for Alkmaar as well, even though the town was in a marshy area.

With regard to the non-specific stress markers, Lewis (1999, 2002) found a similar pattern: enamel hypoplasia and cribra orbitalia prevalence were not increased in the English medieval urban collection in comparison with the earlier and later rural collections. In addition, although the urban sample she studied might have had a higher socioeconomic status, she found similar growth profiles for the rural and urban skeletal assemblages (Lewis 1999, 2002). This study suggests that migration to towns in England was not responsible for a rise in stress levels. Betsinger (2007), who compared urban individuals through time, did not encounter any differences in stress markers between the collections she studied in Poznań, Poland. The results of her study likewise suggest that increased urbanisation did not visibly impact stress levels. Quintelier (2013) found similar results when studying the urban population of Tongeren, Belgium, through time. She also did not observe an increase in stress levels as urbanisation intensified (Quintelier 2013). In contrast to these studies, Kjellström (2005), who compared individuals dating to different phases of urban development from the Swedish medieval city of Sigtuna, noticed an increase in non-specific stress markers in the later phases. Mean stature of the women dating to the later period also decreased. She links this deterioration of health to the establishment of a true urban settlement, which in Sigtuna appeared to be associated with poorer living conditions and large scale immigration which increased population density (Kjellström 2005; Kjellström *et al.* 2005).

The unhealthy city?

These regional comparisons show that different patterns in response to urbanisation are encountered, most likely due to local differences in living conditions and hygiene. An important observation, however, is that, most researchers support the finding of this study: the lack of marked differences in stress markers between town and country. These results express the need for a reconsideration of the common view of medieval towns as dirty and unhealthy. Woods, discussing early modern European cities, writes: *"Cities were graveyards, demographic sinks, and there was a clear penalty in terms of life chances to being or becoming a resident"* (2003:30). Since he based his argument on mortality data from 15th-century Italian cities, this remark is probably not far off. However, this image does not seem to apply to the medieval towns of Holland and Zeeland. Even though infectious disease prevalence was higher in Alkmaar, the comparison of non-specific stress markers between the rural and urban collections does not support the idea of disease-riddled towns and the stress-free countryside. Stature and prevalence of enamel hypoplasia and cribra orbitalia were similar.

The fact that the prevalence of non-specific stress markers was not higher in urban individuals may point to more hygienic living circumstances than previously assumed for medieval towns in Holland and Zeeland. While large cities such as Paris or Florence are known to have had major problems with waste disposal (Pitchel 2005; Roberts and Cox 2003), this appears to have been rather well organised in the towns of Holland and Zeeland (Bitter 2007b; van Oosten 2014). Van Oosten, who researched the cesspit system in Alkmaar, noted that keeping the important waterways free from waste was most likely economically motivated: clean water was necessary for making beer and cloth. While probably not the main concern of the citizens, the waste-free canals had a clear health benefit as well. Additionally, houses in Alkmaar were generally made out of wood (Bitter 2007b) which would have ensured better ventilation than stone buildings. The relatively 'healthy' character of Alkmaar is also noted by the famous medieval physician Pieter van Foreest, who mentions that the sea breeze, the spacious streets, and the good flow of water in the broad canals guaranteed the health of the town (Vis 2007).

6.2.3 Summary: influence of medieval developments on disease

The prevalence of stress markers indicate that the late medieval developments had no marked influence on the rural populations: prevalence remained similar through time. Interesting, the skeletal data also suggest that the image of the town as a disease-riddled demographic sink is not applicable to Holland and Zeeland in the medieval period. While tuberculosis was present in Alkmaar citizens, this disease has not been found in skeletal collections of contemporary towns in Holland and Zeeland such as Dordrecht and Delft. Furthermore, although respiratory infections were more common in Alkmaar, there are no differences in stress markers between the rural and urban collections. This suggests that health disruptions were present in both living environments the Middle Ages. An important observation here is that the skeletal data from Holland and Zeeland studied in this research suggest that the living conditions in towns were not necessarily worse than those in the country. Both living environments appear to have had their own threats with regard to disease which resulted in the presence of skeletal stress markers and certain diseases.

6.3 ACTIVITY AND MEDIEVAL DEVELOPMENTS

A second aim of this research was to assess if specific socioeconomic developments in the medieval period influenced activity patterns. This was done through the comparison of the prevalence of osteoarthritis and bone morphology between three skeletal assemblages. Specific attention is given to differences in the gendered division of labour between villages and town. Unfortunately, limited data on osteoarthritis (only crude prevalence is known) and no data on bone morphology are available for the comparative skeletal collections.

6.3.1 Rural comparisons

Osteoarthritis and activity

The overall or crude prevalence of osteoarthritis (i.e., the number of adults with one or more affected joints) is low in the Blokhuizen collection, at 11.9%. The crude percentage is higher in the contemporary rural skeletal collection of Vronen (29%). The age distribution in the collections is similar which ensures that the observed differences are not the result of variations in the age compositions. A possible explanation for the low crude osteoarthritis prevalence in Blokhuizen is the relatively poor preservation of joint surfaces. Therefore, the analysis of the true osteoarthritis prevalence, which takes into account how many joints are present, gives a more realistic image. The true osteoarthritis prevalence in the Blokhuizen collection is 4.4%.

In Klaaskinderkerke, the crude osteoarthritis prevalence is much higher than in Blokhuizen (28%). This difference can most likely be explained by the better preservation of the Klaaskinderkerke skeletons. This is supported by the fact that there is only a small difference in true prevalence between the two skeletal assemblages: the Klaaskinderkerke individuals have 4.7% of their joints affected by osteoarthritis. The small difference in true osteoarthritis prevalence between Blokhuizen and Klaaskinderkerke points to similar activity patterns for both groups of villagers. In Holland agricultural activities, specifically arable farming, were reduced as a result of subsidence of the peat soils during the late medieval periods (Hoppenbrouwers 2001; van der Linden 1982), but this was not the case in Zeeland. The clay rich soils were not affected as much by subsidence and arable farming could continue into the late medieval period. Even though pastoral farming became important in Holland, in Zeeland, the emphasis remained on crop cultivation (van Steensel 2012b). The fact that both the Blokhuizen and Klaaskinderkerke individuals were mainly occupied with arable farming and were therefore engaged in similar levels of physical activity, may explain the lack of difference in the overall true osteoarthritis prevalence.

However, if the joints are studied separately, some differences are noticeable which may point to variation in the types of activities that were carried out in the two villages. Although the

observed difference does not reach statistical significance at the 0.05 level, the Klaaskinderkerke individuals had a higher prevalence of spinal and especially hip osteoarthritis in comparison with individuals from Blokhuizen. It is likely that the Klaaskinderkerke individuals placed more strain on their backs and hips in comparison with the earlier rural peoples of Blokhuizen. Additionally, in Klaaskinderkerke, osteoarthritis was significantly more common in the lower limbs, while in Blokhuizen the differences between the two joint groups were much smaller. Thus, even though overall true osteoarthritis prevalence does not reveal any differences between the two rural sites, the separate comparison of the joints and joint groups does demonstrate variation. Changes in physical labour are deemed to be the most likely cause of the significant differences in osteoarthritis.

The variations in osteoarthritis prevalence between joint groups and specific joints may have been related to the emergence of a market economy and the reduction of self-sufficiency in the late medieval period. While the inhabitants of Blokhuizen were most likely only producing crops for their own use, the late medieval villagers of Klaaskinderkerke were engaged in more market-oriented commercial arable farming resulting in a surplus that could be sold on the market. Moreover, agriculture in the late medieval countryside was not only focused on food production. The cultivation of certain crops used in the urban industries became important in the late medieval period. The production of madder was of great commercial significance in Zeeland. The red dye, extracted from the roots of the plant, was used to colour cloth and other textiles (van Steensel 2012b).

However, the introduction of other activities besides arable farming in the late medieval period most likely had a more direct impact on activity patterns, and may be responsible for the differences between these two rural communities. In addition to agriculture, the extraction of peat (*moernering*) from underneath the clay was one of the main activities in the countryside of Zeeland (Dekker 1996; Leenders 1999, 2004; van Steensel 2012b). Although damaging to the landscape, the salty peat (*darink*) was necessary for the production of salt and, to a lesser extent, for fuel. Particularly the demand for salt as a means of food preservation increased in the late medieval period, especially due to the development of the herring fishery (Dekker 1996; van Dam 2006; van Steensel 2012b). The on-board gutting and salting of herring ensured that the fish would not rot during transport. This sea fishing, for herring and other fish, became another significant activity for villagers in Zeeland from the 13th century onwards (Bennema and Rijnsdorp 2015; van Steensel 2012b; Unger 1978). This commercialisation of labour in the countryside in the late medieval period may account for the variation in osteoarthritis between the joint groups observed between Blokhuizen and Klaaskinderkerke. While arable farming was a main activity in both villages, the more market-oriented production and the increase of non-agrarian activities in the late medieval period most likely resulted in variations in mechanical loading and therefore in the differences in patterns of osteoarthritis.

Osteoarthritis and male-female differences

No significant differences in the true prevalence of osteoarthritis were found between the males and females in Blokhuizen. This suggests that the activities that were carried out in the village resulted in a similar overall amount of mechanical loading on the joints of both sexes. However, a separate analysis of the upper and lower limbs does reveal differences between the males and females of Blokhuizen. Women have significantly more osteoarthritis in their upper limbs than men. This results points to differences between male and female occupation in rural Blokhuizen.

Historical data on male and female rural activities indeed suggest differences in tasks. Women in agrarian communities in Holland were involved in several activities associated with food production such as baking bread and brewing beer. Another common task of rural women was the spinning of wool and linen. Men are expected to have performed more of the jobs related to arable farming (Kaptein 2007). Historical research on labour in the English medieval countryside presents a similar image. Village women were occupied with a wide range of agricultural activities such as sowing, weeding, reaping, and gleaning, while the men were commonly tasked with activities such as ploughing, an exercise commonly seen as more strenuous (Jewell 1996). Additionally, women were often responsible for taking care of the children and animals, as well as the household, which included tasks such as washing and cleaning (Jewell 1996). The osteoarthritis results suggest that female activities placed more mechanical loading on the upper limbs, while the forces exerted during the male tasks are more equally distributed throughout the body. This pattern of osteoarthritis seems to fit historical information about the activities which were common for women in an agricultural village. Indeed, female tasks may have placed a heavy burden on the upper limbs. For example, the washing of clothes, viewed as a woman's job, required manual beating and pounding of the fabric (Rawcliffe 2009). Other common female activities such as milking cows, churning of butter, and caring for animals (Mate 1999) may have required more from the upper limbs in comparison with the lower limbs.

In Klaaskinderkerke, there were also no significant differences in overall true osteoarthritis prevalence between males and females. In addition, the comparison of the osteoarthritis prevalence in upper and lower limbs revealed no significant sex differences. What does stand out is the high prevalence of hip osteoarthritis in the male individuals of Klaaskinderkerke. Fourteen percent of the studied male hip joints demonstrate signs of osteoarthritis while only 6.5% of the females were affected. Even though this is not clear from the other comparisons, it suggests that the males and females in Klaaskinderkerke were involved in different tasks which predisposed the men to developing hip osteoarthritis. Physical activities that, according to modern clinical research, are associated with hip osteoarthritis include long periods of standing, walking long distances, excessive bending and kneeling, lifting, climbing, and/or

moving heavy objects (Felson 1994:65), all of which can be associated with a wide range of activities.

The comparison of true osteoarthritis prevalence between the sexes in Blokhuizen and Klaaskinderkerke reveals no significant differences in the total number of affected joints. Males and females had a similar overall prevalence through time. However, significant differences become apparent when the upper and lower limbs are compared separately. The Blokhuizen women had a significantly higher prevalence of osteoarthritis in the upper limbs, particularly the shoulder, in comparison with the Klaaskinderkerke women. A different trend is visible for the men: the Klaaskinderkerke males had a higher percentage of lower limb osteoarthritis, especially in the hip, although this difference does not meet statistical significance. These variations between the males and females of Blokhuizen and Klaaskinderkerke point to differences in the rural activities and may suggest that the socioeconomic developments in the medieval period resulted in changes in occupation for both men and women. As discussed above, the more market-oriented crop cultivation and the increase in non-agrarian activities in the late medieval period may have altered mechanical loading and therefore the risk for osteoarthritis. The comparison of male and female osteoarthritis between Blokhuizen and Klaaskinderkerke points to activity changes through time.

Additionally, the separate comparison of the different joint sites reveals clear differences between the males and females of Klaaskinderkerke and Blokhuizen. The Klaaskinderkerke men and women have a higher prevalence of spinal osteoarthritis in comparison to Blokhuizen. Differences in spinal osteoarthritis are difficult to interpret. While a higher prevalence could suggest increased mechanical loading on the vertebral column, there is some controversy over the relationship between spinal osteoarthritis and activity (Weiss and Jurmain 2007). Knüsel *et al.* (1997) found that spinal degeneration was a poor indicator for occupational stress. Moreover, these authors noted that differences in osteoarthritis prevalence were more likely to reflect differences in the curvature of the spine rather than occupational variations (Knüsel *et al.* 1997). Considering this, the observed differences in spinal osteoarthritis between Blokhuizen and Klaaskinderkerke are difficult to interpret and might be the result of other, more morphological, differences between the two groups of people. In contrast, the clear difference in the prevalence of hip osteoarthritis between the males of the two sites does suggest a change in mechanical loading on that joint. Possibly, the increase in distances travelled by foot as a result of regular visits to the newly formed urban centres can be related to the higher prevalence of hip osteoarthritis for the Klaaskinderkerke men. Additionally, the increase in non-agrarian activities such as herring fishing and commercial peat extraction for salt may have altered the daily work, and thereby mechanical loading, of the late medieval male villagers.

Bone morphology and activity

Another possible way to detect differences in activity patterns is the study of lower limb bone morphology. As outlined in chapter three, individuals with a flat bone shape, indicating directional muscle pull, are more likely to have been more mobile and physically active than individuals with rounder bone morphology. In Blokhuizen, both the femoral and tibial shapes are relatively flat indicating high activity levels. In contrast, the Klaaskinderkerke individuals had, on average, rounder bone shapes. This is most apparent when the males from Blokhuizen and Klaaskinderkerke are compared: both the femoral and tibial shapes are significantly different. The rounder leg shape of the males in Klaaskinderkerke indicates less directional muscle pull, which could be related to a change in activity patterns. Interestingly, the Klaaskinderkerke men had a higher prevalence of osteoarthritis in their lower limbs, especially in their hip joints. Thus, both skeletal markers point to a change in male activity patterns through time. Possibly, the increase in commercial activities, such as peat extraction which would increase mechanical loading while reducing mobility, can be responsible for this shift in male activity patterns. Additionally, commercial fishing may have required more mechanical loading on the lower limbs, and can be another explanation for the differences between the Blokhuizen and Klaaskinderkerke men.

The differences between the females of the two rural populations are less clear. The Klaaskinderkerke women have significantly rounder femora in comparison with the females from Blokhuizen. However, the comparison of tibial shape reveals no significant difference, which makes it difficult to comment on whether or not the activities of the women changed through time on the basis of bone morphology data. Interestingly, however, a shift in female activities is suggested by the osteoarthritis data. Since the main osteoarthritis difference is visible in the comparison of the upper limbs, this may explain why the comparison of female morphology of the lower leg bones does not reveal a similar pattern. Directional muscle pull as well as mechanical loading of the lower limbs seem to have remained similar, while mechanical loading of the upper limbs appears to have decreased through time for the late medieval women.

Changes in male-female differences through time

In addition to the clear differences between the men of Blokhuizen and Klaaskinderkerke, there appears to be a shift in the skeletal expression of the sexual labour division through time. Although some differences in shape between males and females are expected as a consequence of anatomical variation, the males from Blokhuizen have significantly flatter tibiae and femora than the females, indicating more directional muscle pull for men. This may point to a more pronounced sexual division of labour in the Blokhuizen people. In particular, this finding is suggestive of higher mobility in the men. This is consistent with historical information that notes that men were more commonly worked in the agricultural fields (Jewell 1996; Kaptein

2007). This did not necessarily require them to walk long distances, but activities such as ploughing may have resulted in substantial muscle pull on the lower limbs. The women appear to have been less mobile which may fit with the idea that they were more concerned with tasks in and around the house (Jewell 1996; Kaptein 2007), with the osteoarthritis data indicating that their activities were strenuous for their upper limbs.

Interestingly, there are no significant differences in bone morphology between the men and women of Klaaskinderkerke. This does not necessarily mean that men and women were performing similar tasks, but it does suggest that the activities they were carrying out required equal levels of muscle pull, possibly that there was less of a difference in their average cumulative mobility. A similar image is presented by the comparison of osteoarthritis prevalence between men and women. Only the prevalence of hip osteoarthritis is suggestive of differences in mechanical loading. This lack of variation in both muscle pull and osteoarthritis between men and women from Klaaskinderkerke could be related to the commercialisation and diversification of labour in the countryside in the late medieval period. With the addition of other occupations besides agriculture, there were more variable activities that may have been more equitably distributed amongst males and females. A possible result of this could be that male and female muscle pull and mechanical loading would have become more similar. The variety of activities may have obscured male-female activity differences as visible in the skeleton. Additionally, sea fishing, so important in Zeeland in the late medieval period, resulted in men being away for extended periods of time, possibly requiring the women to take over some of the tasks previously executed by the men. This may have lowered the mobility of the men and increased the mobility of the females, such that the final outcome was similar, explaining the lack of difference between the sexes.

Shifting activities through time?

Based on the skeletal data, differences in the activity patterns of the rural individuals are visible when the two villages are compared. It has to be noted that there might have been certain local differences between Blokhuizen and Klaaskinderkerke which may explain some of the variations in activity patterns irrespective of the developments in the late medieval period. Differences in environment, soil type, and consequently types of agriculture are likely to have influenced patterns of osteoarthritis and bone morphology. It is to be expected that some of the smaller variations in the type of joints affected by osteoarthritis are due to local variation. However, several of the observed differences cannot be fully explained by intrinsic factors alone. The comparison upper versus lower limb osteoarthritis between Blokhuizen and Klaaskinderkerke demonstrated highly significant differences, which strongly suggests a shift in activity. The comparison of morphology of the lower limbs also reflects shifts in activity patterns. The males from Klaaskinderkerke experienced significantly less directional muscle pull than those from Blokhuizen, which points to a transformation in activity. Additionally,

the Klaaskinderkerke men have a higher prevalence of lower limb osteoarthritis. These observations are congruent with an increased focus on market production and commercial activities, and especially a decrease in agricultural work. Tasks like fishing and peat extraction may increase mechanical loading and reduce mobility. Moreover, the disappearance of strong sexual dimorphism in bone shape in Klaaskinderkerke is also consistent with the commercialisation of activity and the greater variability of occupation resulting in more similar muscle pull for men and women. In sum, the skeletal data on osteoarthritis and bone morphology are suggestive of changes in activity patterns, pointing to increased diversification of physical tasks as a result of the socioeconomic developments in the late medieval period.

6.3.2 Rural-urban comparisons

Osteoarthritis and urban activity

Only 3.9% of the studied joints in the Alkmaar collection showed signs of osteoarthritis. While this prevalence is lower than that of the rural sites, the comparison of the total number of affected joints among the three studied collections revealed no significant differences suggesting that the overall levels of mechanical loading remained similar through time. The intra-site comparison of osteoarthritis prevalence between males and females in the Alkmaar collection revealed significant differences. The men had more joints affected by osteoarthritis than the women. While on average the men were more commonly affected, there were no differences in prevalence in upper and lower limbs between males and females: men just have a higher osteoarthritis prevalence in most joints, suggesting generally higher mechanical loading for the Alkmaar males in comparison with the females. As might be expected, the data suggest that men were involved in more physically demanding tasks.

The separate comparison of the male and female osteoarthritis prevalence between the sites reveals interesting patterns. The comparison of overall prevalence and prevalence in upper and lower limbs of male osteoarthritis between the three skeletal assemblages demonstrates no significant differences indicating that mechanical loading for the men is comparable through time and living environment. Even though the historical data point to increased economic specialisation and a marked decrease in agricultural activities in the towns of Holland and Zeeland, the osteoarthritis data indicate that urban activity patterns did not significantly lower or raise the prevalence of joint disease in men. While it might have been expected that agricultural tasks would result in more mechanical loading on the joints, these results suggest that the urban activities, although different, were responsible for similar levels of physical stress.

The occupations in Alkmaar were quite varied in the late medieval period. While the large scale textile companies decreased in Alkmaar in the 16th century, an increase was noted in traders/craftsmen such as bakers, tailors, shoemakers, smiths, but also weavers and shipbuilders who

were organised in guilds (Kaptein 2007). In addition, individuals within Alkmaar commonly owned land outside of the town, the products of which were sold on the local market, but also exported abroad (Kaptein 2007). Although it is difficult to argue what the occupations of the men in this skeletal sample were, the osteoarthritis prevalence data suggests that a substantial amount manual labour was present in their daily tasks.

The separate comparison of female osteoarthritis prevalence, however, does reveal significant differences. The Alkmaar women have significantly fewer joints affected by osteoarthritis in comparison with the Blokhuizen women, specifically in the upper limbs, indicating that the earlier medieval females experienced higher degrees of mechanical loading on their joints. This suggests that the tasks performed by the rural Blokhuizen women involved more mechanical loading than the activities of the women in the town of Alkmaar. The rural women of Blokhuizen are expected to have been occupied with tasks mainly focusing on agriculture. In an urban context, female tasks were most likely different. The list of individuals buried in the Franciscan cemetery in Alkmaar shows that several women were housewives (appendix 1). Other occupations are unfortunately not mentioned. From Dordrecht, however, there is some information on female occupations within the town. A survey of 492 individuals in AD 1555 found 41 women employed outside the household (Unger 1915). Women worked in the textile business as bleachers, fur processors, spinsters, and seamstresses. In the food industries, women were employed as bakers, brewers, and butchers. Additionally, the Dordrecht survey notes that several women were involved in trade, commonly selling or buying products (Unger 1915). Considering the low number of women included in the survey, it is likely that a large part of the female population was not independently employed. Instead, many women were probably working from home where they were responsible for the household and other tasks associated with the occupation of their husband, as is suggested by English historical literature (Jewell 2007). While this is not indicated in the survey from Dordrecht, Jewell (2007) notes that in English towns, many women, irrespective of marital status, entered household service. Based on the osteoarthritis comparison, it is clear that the Alkmaar females experienced substantially less mechanical loading on their joints which suggests that female rural agricultural activities in the central medieval period were more strenuous than female urban industrial activities. The marked reduction of agricultural tasks replaced by more commercial or household activities for the urban women may have caused mechanical loading to decrease substantially

Interestingly however, there is no difference in osteoarthritis prevalence between the women of Alkmaar and Klaaskinderkerke, while significant variations were observed between the females of Klaaskinderkerke and Blokhuizen. This indicates that urban living is not the only factor influencing activity patterns of the women. The results suggest that the socioeconomic developments in the late medieval period impacted both rural and urban female activities.

The osteoarthritis prevalence suggests that activities with similar levels of mechanical loading were carried out in both town and county. Even though this comparable prevalence of joint disease does not directly imply that they were performing similar tasks, historical literature suggests that late medieval rural and urban activities overlapped. The types of activities were similar (Hoppenbrouwers 2001), even though agriculture would still be important in the countryside, especially in Zeeland (van Steensel 2012b). In the late medieval period, both town and country were highly commercialised and heavily focused on production for the market (Hoppenbrouwers 2001). While the level of specialisation was different, townspeople being more specialised, the fact that they worked in comparable industries may have resulted in similar levels of mechanical loading.

Bone morphology and urban activity

The results of the analysis of bone shape suggest that the Blokhuizen males were experiencing more directional muscle pull than the Alkmaar males: both femoral and tibial shapes are significantly different. However, since there are no differences in muscle pull between the males of Klaaskinderkerke and Alkmaar, which points to similar mobility levels, it is not just the distinction between a rural and urban environment that can explain the marked variation between Blokhuizen and the other populations. As was suggested by the osteoarthritis data, the results from the bone morphology comparisons support the idea that the socioeconomic developments in the late medieval period impacted the activity patterns of both rural and urban individuals. As discussed above, the activities between the late medieval rural and urban populations overlapped. Both the osteoarthritis and bone morphology data indicate that in the case of the men, urban living did not impact significantly on activity patterns. It appears that the transition from the central to the late medieval period had a more substantial effect on activity patterns.

There is a decrease in female muscle pull levels as a result of living in an urban environment. While femoral shapes are similar between Blokhuizen and Alkmaar, the tibial shape is significantly different. Since the tibia is more reliable for studying activity (Pomeroy and Zakrzewski 2009), the differences in the tibial shape tentatively point to reduced muscle pull for the Alkmaar women in comparison with those of Blokhuizen. The comparison between the females of Klaaskinderkerke and Alkmaar gives highly significant results for both the femur and the tibia. The results, however, are somewhat contradictory: the Klaaskinderkerke women have rounder femora and flatter tibia than the women in Alkmaar. Since the tibia, as was noted above, is considered to be more reliable for studying activity, these results hint at higher female muscle pull levels in Klaaskinderkerke in comparison with Alkmaar. This suggests that, while no change was noted in the men, the change from a rural to an urban environment transformed female activities: mobility was lowered, possibly as a result of more work taking place in and around the house.

6.3.3 Summary: influence of medieval developments on activity

The data on osteoarthritis and bone morphology suggest that socioeconomic developments of the medieval period impacted activity patterns. General levels of osteoarthritis remained similar through time, but differences in prevalence in specific joints or joint groups point to a transformation in activity. The bone morphology data has demonstrated marked differences between the populations suggesting a shift in activity patterns. The most important conclusion is that the largest differences are not between the rural and urban collections, but between those from the central medieval and late medieval periods. Both men and women from Blokhuizen experienced higher degrees of muscle pull than the individuals from Klaaskinderkerke and Alkmaar. Additionally, the prevalence of osteoarthritis in the upper limbs of the Blokhuizen women is significantly higher than that among the Klaaskinderkerke and Alkmaar women. Another important finding is that the female activity pattern seems to be more influenced by urban living than that of the men. The Alkmaar women experienced lower degrees of muscle pull than the Blokhuizen and Klaaskinderkerke women. These results suggest that the socioeconomic developments in the late medieval period, including the commercialisation of rural industries, more market-oriented production, and the increase in non-agrarian activities in both town and country, may have been responsible for an impact on activity patterns of the late medieval people.

6.4 DIET AND MEDIEVAL DEVELOPMENTS

A third objective of this research was to assess if the socioeconomic developments in the medieval period influenced dietary patterns. This was done through a comparison of the prevalence and frequency of carious lesions and the prevalence of indicators of nutritional stress among the three skeletal assemblages.

6.4.1 Rural comparisons

Caries and diet

By studying caries prevalence, it is possible to gain insight into the type of foods (i.e., proteins or carbohydrates) that were consumed. Populations more dependent on foods rich in carbohydrates often have a higher caries prevalence and frequency. A diet mainly composed of proteins will result in lower caries rates (Hillson 2008). In Blokhuizen, caries prevalence (i.e., the number of individuals with one or more caries lesions) is 41.4%. The overall caries frequency (i.e., the number of teeth showing caries in relation to the total number of observed teeth), which gives a more reliable picture of the amount of carious lesions since it takes into account factors such as differential preservation and post-mortem

and ante-mortem tooth loss, is 7.8%. This pattern is comparable to that of the contemporary village of Vronen where 7.1% of the studied teeth were affected by caries (Alders and van der Linde 2011), suggesting that similar types/proportions of foods were consumed in the two villages.

Caries prevalence in Klaaskinderkerke is significantly higher than in Blokhuizen. Since similar percentages of teeth and tooth types survived at both sites, the caries prevalence data are presumably not an artefact of differential preservation or variations in the amount of ante-mortem tooth loss. Historical, archaeozoological, and archaeobotanical data indicate that the central medieval diet was most likely relatively simple, mainly consisting of cereals and meat (Bakels *et al.* 2000; Ettema 2005). Bread made from the available grains, mainly wheat and barley, appears to have been an important food product (Burema 1953; Jansen-Sieben and van Winter 1989). Fruits and vegetables, on the other hand, were considered lesser food products, beans and cabbage-like vegetables were seen as the least '*kwaadaardig*' (evil) (Baudet 1904; Burema 1953). Moreover, milk products such as cheese and butter, although representing more luxury products, were most likely also consumed. Meat and fish are considered to have been consumed on a regular basis. Although fish bones are not commonly encountered in the central medieval village sites in Holland and Zeeland (Kok 1999), fish was most likely a common meat replacement in combination with eggs (Rawcliffe 2013; van Dam 2009). Since the caries prevalence in Klaaskinderkerke is higher than in Blokhuizen, a dietary shift is suggested by the data, in this case the ingestion of more carbohydrates.

Local variations in preference or availability of certain crops may have been responsible for a different diet causing the observed increase in carbohydrate consumption. In addition, changes in and diversification of agricultural practices as well as intensification of international trade in the late medieval period could have expanded and diversified diet (Woolgar *et al.* 2006). This hypothesis is supported by archaeobotanical and archaeozoological research which shows a greater diversity of fruits and vegetables, and more types of animals in the countryside during later medieval times (van Haaster *et al.* 2001). Indeed, an increase in fruit consumption or the intake of more sugar and honey may have been responsible for the higher prevalence of caries in Klaaskinderkerke. It is, however, difficult to assess if everyone would have had access to these products. Both Baudet (1904) and Burema (1953) state that sweets and cakes were available in late medieval society, but that not everyone could afford them.

Another explanation for the higher caries prevalence may be an increase in alcohol consumption. Studies performed on animals in a laboratory setting show that a higher intake of alcoholic drinks promotes bacterial growth in the oral cavity (Kantorski 2007). During the central medieval period in Holland, beer production on a commercial scale was still in its infancy (Unger 2004). Although small quantities may have been produced at home,

only after AD 1300 did commercial beer production became important (Unger 2004). Therefore, it is possible that beer was consumed on a more regular basis in Klaaskinderkerke causing carious lesions to increase.

However, this potential shift in food consumption did not result in an increase in the number of teeth affected by caries: the overall caries frequency (non-adults and adults combined) in Blokhuizen (7.8%) is comparable to that in Klaaskinderkerke (7.9%). A separate analysis of the adult caries frequency shows similar results. The adults of Klaaskinderkerke had a caries frequency of 8.7% and in Blokhuizen this was 9.1%. The similarity in frequency and dissimilarity in prevalence can be explained by the fact that in Blokhuizen the individuals with caries had many teeth affected.

The women in Blokhuizen had twice as many teeth affected by caries in comparison with the men. The females had a caries frequency of 13.5% while the men only had a frequency of only 7.3%. The trend of women having a higher caries frequency is observed in many skeletal collections from different cultures with different dietary practices (for an overview see Lukacs and Thompson 2008). Dietary differences between men and women are a common explanation for this variation which is frequently related to the notion that women have easier access to food and snack during meal preparation (Lukacs and Largaespada 2006). Another often noted cause of the sexual division is that teeth erupt earlier in girls than in boys, hence increasing exposure time (Lukacs and Largaespada 2006). Lately, a physiological explanation has received attention. Recent research by Lukacs and Thompson (2008) has shown that the hormonal changes associated with pregnancy, and also with puberty and menstruation, result in modifications in saliva composition making the oral environment more cariogenic in women than in men (Lukacs and Largaespada 2006; Lukacs and Thompson 2008). Although dietary differences between males and females cannot be ruled out, the fact that sexual differences in caries prevalence and frequency are commonly present in prehistory and history (e.g., Hemphill 2008; Lukacs and Thompson 2008; Olson and Sagne 1976) makes the physiological explanation highly plausible.

Interestingly, there are no significant differences in caries frequency between males (8.8%) and females (7.4%) in Klaaskinderkerke. If the hormonal explanation is valid, then the actual lack of difference may point to a difference in diet between males and females in this village. These data suggest that the women were eating fewer carbohydrates, since their caries frequency is significantly lower in comparison with the Blokhuizen women. The females from Klaaskinderkerke appear to have been consuming more protein, possibly in the form of meat, milk products, or eggs. More milk products in the diet, especially cheese, would lower caries rates since these food items have protective effects against caries (Hillson 2008). In addition, increased fish consumption may have contributed to the observed decrease in caries. As was

discussed in chapter three, fish-eaters have on average lower caries rates (Littleton and Frolich 1993). Since commercial fishing became an important activity in late medieval Zeeland (van Steensel 2012b), it is possible that the consumption of fish also increased. These hypotheses, however, do not explain why only the caries rates among the women decreased. The caries frequency for the Klaaskinderkerke males actually increased, suggesting greater carbohydrate consumption.

Changes in rural diet?

The caries data suggest that there was a shift in diet from the central to late medieval periods for the females. The caries frequency decreased substantially, suggesting more or different proteins and fewer carbohydrates in the diet. Considering that milk products and fish have a protective effect against caries, this could suggest that women in Klaaskinderkerke were more regularly consuming these food stuffs than the women in Blokhuizen. As commercial fishing became more important in the late medieval period, fish might have been more readily available in Klaaskinderkerke. The men from Klaaskinderkerke, on the other hand, do not seem to have benefitted from the greater availability of fish. The caries frequency of the males is slightly higher in comparison with the males from Blokhuizen, but this difference is not statistically significant. A possible explanation can be that men were consuming more protein in addition to more carbohydrates, maybe in the form of beer, resulting in an overall similar caries frequency in comparison with Blokhuizen. If this is indeed the case, the caries data point to a dietary shift for both males and females in the late medieval period.

Nutritional stress

An evaluation of the skeletal indications for specific nutritional deficiencies suggests that the diet consumed by the Blokhuizen individuals was sufficient in certain nutrients. The characteristic bending of the lower legs associated with vitamin D deficiency was not observed in the Blokhuizen collection, suggesting a healthy intake of food products with vitamin D, most likely meat, fish, and eggs, as well as sufficient exposure to sunlight. Similarly, scurvy was also not encountered in Blokhuizen. While the identification of scurvy in skeletal remains is difficult, the complete absence of the disease suggests that the Blokhuizen diet was most likely sufficient in vitamin C. Citrus fruits are an important source of vitamin C, but several vegetables, especially certain types of cabbage, contain it as well. Archaeologically, fruit remains are rarely encountered in villages dating to central medieval times, especially those on the peat soils. This is most likely the result of the inability of fruit trees to grow on the peat (Bakels *et al.* 2000). Vegetables would then be the most likely source of vitamin C, but these are also hardly ever found during archaeobotanical research, which presumably results from the poor preservation of vegetable remains in archaeological contexts (Bakels *et al.* 2000). Possibly, the villagers supplemented their diet by gathering wild fruits such as blackberries and blackcurrants (Bakels *et al.* 2000; van Haaster *et al.* 1997).

While none of the studied nutritional diseases were encountered in Blokhuizen, there are three pathognomonic cases of residual rickets in Klaaskinderkerke. These cases may point to increased nutritional stress in the late medieval period. However, since there are no significant differences in the prevalence of non-specific stress markers between Blokhuizen and Klaaskinderkerke, and because the Klaaskinderkerke caries frequencies suggest a large component of vitamin D-rich foodstuffs such as fish, it is possible that the increased rickets prevalence has a more behavioural explanation. Considering that sunlight is the most important source of vitamin D, the cases of residual rickets may suggest that the children in Klaaskinderkerke spent more of their time indoors or wore more occlusive clothing than the children of Blokhuizen. Interestingly, all of the individuals with residual rickets were females, suggesting that they were possibly more at risk for developing vitamin D deficiency.

The changes in the activity patterns of the late medieval villagers indicated by the differences in osteoarthritis and bone morphology could have played a role in the observed increase in vitamin D deficiency. Although changes in clothing cannot be ruled out, the late medieval intensification of commercial activities in the rural settlements may have resulted in more tasks being performed indoors, while previously most activities would have taken place on the land. It is possibly that an increase in indoor activities such as spinning and weaving was responsible for the higher prevalence of vitamin D deficiency in the Klaaskinderkerke girls/women. A similar pattern was observed in the English skeletal collections studied by Lewis (1999). She also noted a slight increase in nutritional deficiencies in the later rural assemblage. Considering a similar absence of differences in stress markers between her collections, a behavioural explanation, clothing or more time indoors, was deemed more likely by Lewis as well.

Evidence for late medieval famine?

The fact that no differences in nutritional status are observed between Blokhuizen and Klaaskinderkerke is interesting considering the occurrence of periods of food scarcity in the late medieval period, which could have negatively influenced the nutritional value of the consumed diet. Three back-to-back crop failures as a result of extreme weather conditions throughout Europe in the years AD 1315 to 1317 strongly diminished the availability of agricultural products. Moreover, damp conditions on many of the agricultural fields allowed plant diseases such as mould, mildew, and rust to flourish (Jordan 1996; Blockmans and Hoppenbrouwers 2009). Additionally, the poor weather laid the foundations for the outbreak of deadly animal diseases, affecting predominantly cattle and to a lesser degree sheep (Jordan 1996; Newfield 2009; Slavin 2012). The crop failures and animal mortality resulted in a catastrophic subsistence crisis affecting the entire continent of Europe, including Holland and Zeeland (Jordan 1996). Jordan (1996) estimates that 10% of the population died as a result of the famine which is more than twice the expected mortality rate for the late medieval period. However, evidence of this 'Great Famine' is not visible in the skeletal remains studied in this

research. The prevalence of non-specific stress markers and stature means between Blokhuizen and Klaaskinderkerke collections are similar and large differences in nutritional deficiencies are not observed. Historical sources focusing on this period in time in Zeeland seem to fail to mention the famine (Dekker and Kruisheer 1967). These results could suggest that the famine did not impact the individuals from Klaaskinderkerke to a great extent. However, if the famine was indeed as deadly as Jordan (1996) suggests, several of the Klaaskinderkerke individuals could have died as a result of it without having the time to develop skeletal lesions. This could explain why no increase in stress markers or differences in stature means are noted. Considering the fatality of the famine, it is plausible that some individuals of Klaaskinderkerke died as a result of it without demonstrating an increase in non-specific stress markers.

6.4.2 Rural-urban comparisons

While the difference in caries between Blokhuizen and Klaaskinderkerke is difficult to interpret, the Alkmaar caries results indicate a marked dietary shift. Although variations do not meet statistical significance, the urban individuals had a higher caries prevalence than the inhabitants of both Blokhuizen and Klaaskinderkerke. Moreover, the individuals from Alkmaar had a significantly higher caries frequency than the individuals from the rural populations which suggests a clear increase in carbohydrate consumption by the urban people. This apparent dietary shift is further corroborated by the early onset of caries in Alkmaar. The younger adults in the urban collection have significantly more teeth affected by caries than those from Klaaskinderkerke and Blokhuizen pointing to a clear increase in cariogenic food consumption. These caries data indicate that there is both a dietary shift through time as well as a shift associated with urban living. In the late medieval period a broad variety of foods must have been available in the urban centres as a result of the increase in international trade (van Bavel 2011). However, since both rural and urban people in the late medieval period would have had access to urban markets, the influx of new and different products alone cannot explain the large difference in caries prevalence and frequency between Alkmaar and Klaaskinderkerke. One aspect of urban living that might be responsible for the increase in carious lesions is that townspeople would have had more access to and have been more dependent on the market for food. Although some citizens may have had access to small gardens (Bitter 2007b; Dijkman 2010), agriculture was not a common task for urban people. Even though commercialisation of the countryside in the late medieval period also made villagers more market dependent, they most likely still produced some products and kept animals for their own use, thereby possibly limiting their carbohydrate intake. The more regular market access for the urban citizens would have increased their opportunity to buy products which contained sugar.

A separate analysis of the sexes shows that the Alkmaar men had a significantly higher caries frequency than the men from the two rural collections indicating that they were consuming

different kinds of food products, mainly more carbohydrates. In addition, while the females from Blokhuizen and Alkmaar had a similar caries frequency, the difference between the Alkmaar and Klaaskinderkerke females is much larger, pointing to more starches and sugars in the urban female diet in comparison with village women from the same time period. What the separate analysis of the sexes also reveals is the lack of variation between males and females in caries frequency (16.8% versus 16.7%). As discussed above, throughout history women have commonly had higher caries rates, which suggests that this lack of difference in caries frequency actually points to dietary variation. It suggests that the men in Alkmaar were consuming more cariogenic foods than women, as appeared to be the case in Klaaskinderkerke. Overall, the caries data suggest a clear increase in carbohydrate consumption for the urban inhabitants, especially for the males.

Isotopic case study: Blokhuizen and Alkmaar compared

Stable isotope ratios of carbon and nitrogen from the bone collagen of 50 individuals from Blokhuizen and Alkmaar were analysed in the context of the Master's research of IJk van Hattum (2014) in order to gain insight into their diet. Isotopic ratios differ in different classes of food which are then incorporated into the skeleton (DeNiro and Epstein 1978, 1981; Schoeninger and DeNiro 1984). The analysis of these ratios allows for an estimation of the types of consumed foods and in certain cases the rough proportions of different foods. Generally, a difference can be made between the consumption of marine and terrestrial food products, and between C3 (most European crops) and C4 (tropical and subtropical) plants (figure 6.1) (DeNiro and Epstein 1978, 1981; Schoeninger and DeNiro 1984).

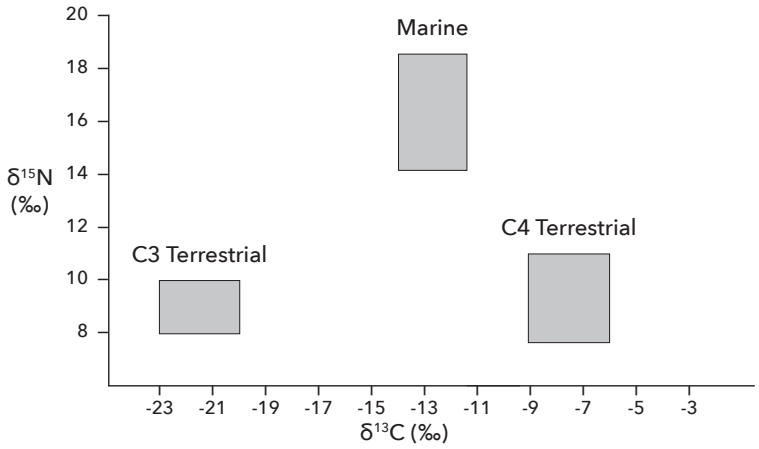

Figure 6.1: Approximate stable isotope ratios when consuming pure C3, C4, and marine diets (after Mays 2010, figure 10.2, p. 270).

The comparison of the isotopic signatures of people of Blokhuizen and Alkmaar suggests a dietary shift. While the caries data point to increased consumption of carbohydrates by

the urban population, especially for the males, the isotopic data indicate that the Alkmaar people, both the men and women, were also consuming different protein types (van Hattum 2014, figure 6.2). These data indicate that the urban citizens consumed products higher up on the food chain, most likely marine or freshwater fish, but also increased intake of omnivores such as chickens (and their eggs) and pigs should be considered. Cesspit research from Alkmaar has shown that a wide variety of proteins were available (Esser *et al.* 2001). Meat consumption appears to have been focused primarily on cattle, pig, and sheep or goat. Birds, mainly chicken and duck, have also been encountered in the Alkmaar deposits, although to a lesser extent (Esser *et al.* 2001). Fish and shell fish were commonly found in the deposits indicating that they were indeed a significant source of food. Especially mussels appear to have been favoured in Alkmaar (Zeiler and Brinkhuizen 2010).

Based on the isotopic data, the diet of the Blokhuizen individuals appears to have been mainly composed of terrestrial food products, most likely cereals and protein from herbivores such as cows (van Hattum 2014). Fish was of less importance in the Blokhuizen diet. As noted above, fish bones are not commonly encountered at the rural wetland village sites (Kok 1999) while they are regularly found in urban contexts (Esser 2003). This may in part be due to differential preservation and excavation techniques, yet, the lack of fish bones in combination with the isotopic data from Blokhuizen suggests that fish consumption was indeed limited in the central medieval villages.

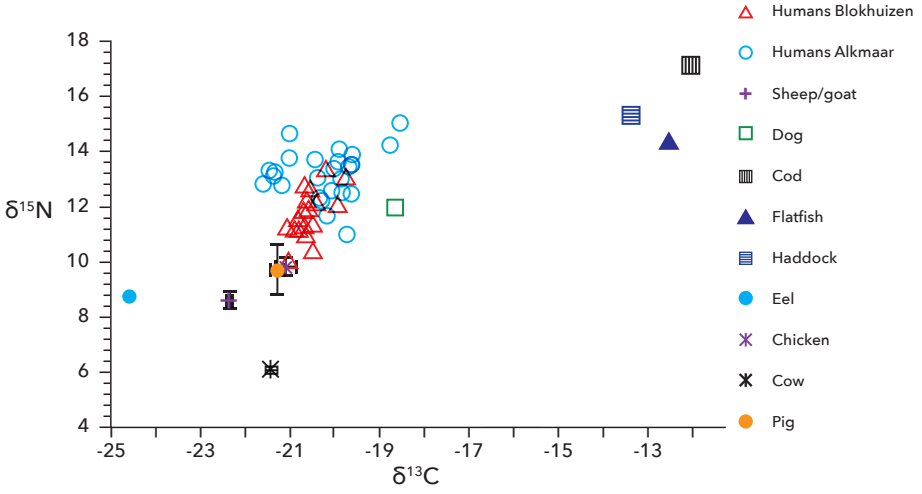

Figure 6.2: Stable carbon and nitrogen isotope ratios of the individuals from Blokhuizen and Alkmaar compared to the average stable isotope ratios from fauna specimens from Alkmaar and the stable carbon and nitrogen isotope ratios from fish samples from Oldenzaal. Error bars are one standard deviation (after van Hattum 2014, figure 10, p. 109).

This observation is consistent with the clear increase in commercial fishing activities during the late medieval period. As mentioned, herring fishing became a significant industry in Zeeland and parts of Holland and herring became an important export product making its way up to England, and even being transported as far as Basel (Unger 1978). Especially the new preservation technique of curing herring on board of the ship (kaken) allowed for export and import over large distances. According to Unger (1978:338), *"From 1439 to 1441 about 375 lasts of herring went from the province of Holland alone to Germany"*. Since a last is approximately 1000 kilograms, vast amounts of herring were caught in the late medieval period of which a good portion was exported. However, a large portion also made it to the markets in Holland and Zeeland (Unger 1978). In addition to locally procured fish, stable isotope research on fish bones dating to the late medieval period indicate that fish was also imported from distant waters such as arctic Norway, Iceland, and/or the northern isles of Scotland (Barret *et al.* 2011).

As a result of increased water management, especially the creation of dikes and sluices, eel fishing became important in the late medieval period (van Dam 1997). The associated expansion of fresh water resulted in an increase of eels in Holland. Eels are comfortable in the peat environment of Holland, with its shallow water. Furthermore, the fact that eels migrate from fresh to salt water at some point in their lifetime made them travel to the sluices where they could be caught by fishermen (van Dam 1997). While this development could have expanded the availability of eel on the markets, the isotopic data do not suggest a marked increase in eel consumption in the late medieval period, suggesting that this fish may have been a more minor part of the diet. This is further supported by van Dam (2003) who notes that large portions of eel are exported to oversee ports which might explain the apparent lack of local consumption.

The isotope data also demonstrate that the individuals from Alkmaar had a more heterogeneous diet than the people of Blokhuizen. Most inhabitants of Blokhuizen appear to have been consuming similar food products. Male and female isotopic ratios were similar, suggesting that there were no marked sex-based differences in diet (van Hattum 2014). This also supports the hypothesis that the difference in caries frequency between the Blokhuizen males and females had a hormonal origin and was not the result of large dietary differences. In Alkmaar, however, there were differences in the stable isotope values of males versus females suggesting a more marked difference in diet (van Hattum 2014). The increase in the type of products that were available as a result of the expansion of the market, and thereby the likely diversification of the diet in the late medieval period may have contributed to this. The decreased reliance on home grown foods could have resulted in larger differences in diet within the urban population.

Nutritional stress

The skeletal remains from Alkmaar do not provide any evidence for a change in nutritional stress. Only one individual shows signs of a possible vitamin C deficiency. Skeletal lesions associated with vitamin D deficiency were not encountered. As noted above, none of the skeletal indicators for nutritional disease were found in Blokhuizen. Three cases of vitamin D deficiency were documented in Klaaskinderkerke, but it is argued that this increase in prevalence has a sociocultural explanation. Considering the similarities in the prevalence of enamel hypoplasia, and the lack of difference in stature means, large differences in nutritional status are unlikely.

6.4.3 Summary: influence of medieval developments on diet

The comparison of the caries rates tentatively shows the late medieval diet contained more cariogenic products than that of previous times. In Klaaskinderkerke more individuals were affected by carious lesions than in Blokhuizen suggesting increased consumption of carbohydrates. However, the comparison of the caries frequency does not follow the same pattern. The comparison of the urban and rural individuals gives stronger results: a clear increase in caries prevalence and frequency is observed, suggesting higher consumption of cariogenic products. Increased consumption of sugar-rich fruits could have contributed to the higher caries rates in the urban collection. It is possible that higher market dependence was responsible for the increased consumption of cariogenic foods. Furthermore, an isotopic case study of a small sample of individuals from Blokhuizen and Alkmaar demonstrated that in addition to the increase in carbohydrates, the Alkmaar townspeople were consuming different types of protein, most likely more marine or freshwater fish which is in line with the increase in commercial fishing and the greater availability of fish in the late medieval period. Furthermore, the isotopic data indicate increased dietary heterogeneity in the Alkmaar population, which can be linked to their greater dependence on the market for food.

The analyses of caries and stable isotopes indicate that the urban diet in the medieval town of Alkmaar was different from that of Blokhuizen and Klaaskinderkerke. Lewis (1999, 2002) also reported a statistically significant increase in carious lesions in the dentitions of urban non-adults, a pattern which she also links to greater access to imported and refined foods. Moreover, Kjellström (2005) notes an increase in the prevalence of carious lesions when the urban settlement of Sigtuna became more established. Although she does not relate this specifically to a larger component of imported foods, she notes it was most likely related to increased carbohydrate consumption. Interestingly, Betsinger (2007) noted no differences in caries prevalence between the three consecutive urban Polish collections she studied, indicating that the diet, or at least the proportions of proteins to carbohydrate, remained similar throughout urban development (Betsinger 2007). Since Betsinger studied collections

dating from AD 950 to 1250, it is possible that international trade and market exchange in that period were not yet at the level of late medieval England and Holland, therefore limiting the availability of imported and refined foods.

With regards to nutritional stress, no significant differences are visible between the collections. This is consistent with the lack of difference in the non-specific stress markers. Nutritional deficiencies were not found in Blokhuizen and Alkmaar. The presence of residual rickets in Klaaskinderkerke is considered to have a behavioural explanation, considering the similar prevalence of non-specific stress markers and comparable stature means. Although the Great Famine between AD 1315 and 1317 could have influenced mortality rates and stress marker prevalence, this is not visible in the excavated population of Klaaskinderkerke. Although this may suggest that the famine was not as influential in Zeeland as it was in other areas in Northern Europe, it is necessary to consider the possibility that some of the Klaaskinderkerke individuals may have died as a result of the famine before developing any signs of a pathological stress response.

6.5 OSTEOARCHAEOLOGY AND MEDIEVAL SOCIOECONOMIC DEVELOPMENT

The main goal of this research was to osteoarchaeologically study the socioeconomic developments of the medieval period and associated life consequences. This bottom-up approach aimed at increasing our understanding of the physical impacts of medieval socioeconomic changes. Historical data show that the medieval period in Holland and Zeeland can be characterised as a period of substantial change and development during which the foundations were laid for the prosperous Golden Age of the 17th century. Large scale urbanisation, optimisation of rural and urban industries, and the development of extensive international trade networks in the late medieval period triggered a blossoming Dutch economy. This study has provided new and unique perspectives on these historical developments, by adding physical information on individuals to the existing body of historical data.

The comparison of the skeletal remains from Blokhuizen, Klaaskinderkerke, and Alkmaar has demonstrated that the developments in the late medieval period were not limited to socioeconomic consequences but also impacted the medieval citizens physically. Changes in disease, activity, and diet are indicated by several of the skeletal markers studied in this research.

However, although the opposite might have been expected on the basis of other research (e.g., Woods 2003), marked differences between town and country appear to be absent,

especially in the late medieval period. The largest differences are found between central medieval Blokhuizen and the two late medieval skeletal collections, especially in terms of activity, which indicates that socioeconomic developments in the late medieval period not only influenced the citizens of the newly formed towns, but simultaneously left their mark on the rural villages from the same time period. While there are small variations suggesting that rural and urban living environments were different, also in the late medieval period, generally speaking, this research does not uphold a marked rural-urban dichotomy, rather supporting the idea of a relatively fluid and interdependent relationship between town and country in the late medieval period.

Another important observation that can be made on the basis of the data presented in this chapter is that comparable research carried out in other places in Europe has found both similar and different skeletal patterns. This reinforces the unique contribution of the current research, yet also expresses the need for more local osteoarchaeological analyses focusing on similar topics in Europe to achieve a nuanced and accurate view of the changing European society in this dynamic era. Extrapolating what is known about the consequences of urbanisation and other developments in the medieval period from certain regions to other areas might result in incorrect conclusions. As this research has shown, it is vital to have a good understanding of local factors influencing populations to be able to draw refined and informed conclusions about the physical consequences of medieval socioeconomic developments.