Establishing the paleodemography of S: t Nicolai High Medieval cemetery

- An evaluation study of the Transition Analysis 3 method

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Abstract

Paleodemography is the study of evaluating and reconstructing ancient populations based on the processes of fertility, mortality and migration. In addition, structural variables such as life expectancy, population distribution and population density are included in order to calculate the demography of a given population at a given time. The paleodemographic processes and variables are all dependent on the factors of age and biological sex. Methodology in osteological age estimation has traditionally been unable of estimating accurate ages in older adult individuals, however, developments in the field has yielded improved methods, Transition Analysis 3 being one of these. Transition Analysis 3 uses machine learning, basing the results on regression analysis rather than age mimicry that automates analytical model building. The method has proven greater ability in estimating adult older ages than traditional methods. Traditional methods often use single trait assessment while Transition Analysis 3 use multi trait assessment, making it usable for taphonomically challenged skeletons. Transition Analysis 3 has since its development in the early 2000's been revised and improved twice and the third and most recent version has not yet undergone public extensive testing. Transition Analysis 3 is applied in this study for the purpose of testing the third version of the method as a mean to establish the paleodemography of S: t Nicolai cemetery in 13th-14th century CE Helsingborg. The age of 75 individuals were assessed, 67 of which by using the Transition Analysis 3 method. The results of the age estimations using Transition Analysis 3 indicate that life expectancies were higher than previously reported in European Medieval populations. The paleodemography of the cemetery indicates that the individuals represent a constructed populatory composition stemming from socioeconomic factors and institutionalized burials rather than those of a typical parish. The evaluation of the Transition Analysis 3 method demonstrates validatory methodological prerequisites, however, framework regarding inclusion critera might improve methodological usage and interpretation.

Keywords: *Paleodemography, Transition Analysis, Middle Ages, Helsingborg, Osteology*

The author made all tables. The author made figures 2- 5.
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1. Introduction

The ultimate goal of paleodemography is defined by Bullock et al. (2013) as detecting the correlation between health and society. The study of paleodemography is used for evaluating and reconstructing past populations based on mainly three processes; fertility, mortality and migration. In order to do so, it is necessary to include structural variables such as life expectancy, population distribution and density (Meindl & Russell, 1998; Monge & Mann, 2015; Baitzel & Goldstein, 2016). Life expectancy, stature and senescence provides indications of good or poor health in a population. Paleodemography is especially important for those populations or cultures that have no written sources, remaining or never written down, for contemporary societies to understand how ancient lives might have been constructed (Buikstra & Koningsberg, 1985). Séguy & Buchet (2013:1) makes a distiction between paleodemography for populations without written sources and historical demography for those that do. Nancy Howell, one of the early frontrunners and believer in the study of paleodemography described the subject as being ”intensely interesting and devilishly difficult” (Howell, 1976:25). This notion sums up what many researchers after her have concluded, and it is a field of study that is in constant transformation and development. It is also one of few areas where the foundational methods are constantly discarded and replaced by other, more reliant ones (Buikstra & Koningsberg, 1985). The methods used have always recieved critique from all around the field, and also from the field of demography, however the criticism has mostly been constructive and paved way for better methods to develop. During the 1980's, paleodemography underwent a much-needed first renaissance and was refined in a way that heavily increased the quality of data included in the research (Hoppa, 2002:18). Paleodemography had long been conducted with much too weak material on much too big conclusions were drawn from the results. The field of paleodemography took great impact and lost a lot of its credibility as a result. When paleodemography transformed, demographers and statisticians provided with their expertise, and a greater collaboration was formed in order to help with the conceptualization of population dynamics (Howell, 1986; Meindl & Russell, 1998). The main difficulty with paleodemography lays within the absence of process marks on the archaeological record, in this case, the bones of adult individuals.

When reaching the third decade of life, the variations in the ageing processes increases as effects of genetic and environmental factors (Meindl & Russell, 1998). The rapid need for development in age assessment for adults have also been heavily requested by medicolegal investigations and forensic contexts since the age of a person can be a crucial factor for identification (Getz, 2017:1). The issue with methodological age mimicry bias can have severe consequences for this reason.

There are not currently, nor have not been, any two individuals who have been utterly identical. We all consist of the same basic compounds, have the same shape, but during our lifetimes, we will make different choices, be exposed to different experiences, illnesses and accidents. We will consume similar, but not identical diets, as others. We will have different genetic sets making us more resiliant or frail to what we encounter (Howell, 1986). This constitutes the difference between chronological age and biological age. Every single individual will have different paths to senescence (Getz, 2017:8). The principle also applies to populations. When investigating archeological contexts, there will also be differences in how we were deposited and what that deposition has meant for the preservation of our bones. The processes of fertility, mortality and migration often leave little trace on the bones.

1.1 Purposes & Aims

Paleodemography is important to understand the relationship between health and society in a given population. By identifying processes of fertility, mortality and migration, paleodemography is possible to apply (Bullock et al., 2013). Fertility might be the key factor to unlocking paleodemographic studies but has proven difficult to calculate, and results from migratory research have mostly proven inconclusive and it is therefore mortality that most paleodemographic research is based upon (McFadden & Oxenham, 2018). Included in the concept of mortality, longevity is a common factor. In order to calculate longevity, it is necessary to know the ages-at-death of the studied individuals (Meindl & Russell, 1998). The methods for assessing age-at-death have historically been substandard and thus affected paleodemographic research negatively, systematically over-ageing young adults, under-ageing old adults and skewing results to make longevity and mean ages far lower than they really are (Milner & Boldsen, 2012).

Scholars have been aware of the methodological issues since the 1980's but have had difficulties to rectify this problem. The relatively new method for age assessment called Transition Analysis (TA) has proven on multiple occations to be a more accurate and inclusive method than traditional age assessment methods (Milner & Boldsen, 2012). The individuals from S: t Nicolai cemetery has not previously undergone a proper osteological analysis and no paleodemographic study of the material has even been made. By extracting variables of age and sex using the most reliable methods avaliable, a first ever paleodemographic study of the population buried in S: t Nicolai cemetery can be conducted in order to visualize life courses in High Medieval Helsingborg.

The purpose of this study is dual. The first purpose is to test the third version of Transition Analysis. The second purpose is that by using Transition Analysis 3 on human skeletal remains, establish a paleodemography of the High Medieval population that was buried at S: t Nicolai cemetery.

1.1.1 Questions & Hypothesis

- Is Transition Analysis 3 a usable method for assessing age on the S: t Nicolai material?
- What is the paleodemography of S: t Nicolai using TA3?
- In what way does the paleodemography using TA3 differ from previous paleodemographic studies of Medieval Denmark?
- In what way does the paleodemography of S: t Nicolai using TA3 differ from paleodemographic studies of High Medieval populations in Europe?

The hypothesis of this study is that there is a difference in paleodemography conducted by using different methods. The methods previously used on similar populations are known for underageing old adult individuals and underageing young adult individuals. The hypothesis is also that by using improved and more accurate age assessment methods, the information about individual humans can also be enriched and altered.

1.2 Problems with paleodemographic methods

The main topic for this thesis is paleodemography. In order to properly investigate and estimate paleodemography for any population, the methodology is the key factor. By pointing out weaknesses and limitations with methods, these can be improved. Also, by testing evolved and improved methods within the field, progress can be made and the calculations of paleodemography become more and more accurate. Konigsberg & Frankenberg (1992) identified three main pitfalls when investigating paleodemography: the rate of population growth is rarely known, the sampling may not be representative and ages are almost always estimated rather than known. These factors need to be considered when applying methods to the theory. Boucquet-Appel & Masset (1981) found two additional pitfalls with regards to leaving out old people out of the distributions. The issues were the use of classification systems and the demographic estimations. The classification systems vary with each study and the demographic estimations make assumptions about carrying capacities and how many children have been produced. The authors find these estimations to be based on guess rather than science and should not be used. By making these assumptions, paleodemographic research have indicated early mortality, over-mortality of women and an absence of old people in the studied populations (Meindl & Russell, 1998). Boucquet-Appel & Masset (1981) connects the misuse of the paleodemographic data to a lacking knowledge on demographics and statistics, something that Howell (1976) has also adressed. A year after Boucquet-Appel & Masset (1981) published their critique on how archeologists interpreted the remains of dead people in demographic circumstances, Wood et al. (1992) published their article on the Osteological paradox, connecting to Boucquet-Appel & Masset's (1981) article and the fact that osteological data needs to be viewed in a mirror reflected approach in order to make assumptions on mortality, fertility and endurance.

1.2.1 The Rostock manifesto

Paleodemography rests upon processes of fertility, mortality and migration. These processes are dependant on structural variables, which can be determined by using sex and age estimates. The data that can be extracted from these estimates can be useful for understanding health related indicators in past societies, interpret adaptive occurences and behaviours. Therefore, it can identify social success and evolution and also establish baselines for bioevolutionary gene flow and gene drift. Up until 1999, the tools needed to properly and scientifically establish such a baseline was non-existing, resulting in the Rostock Manifesto (DeWitte, 2006:36; Knudson & Stojanowski, 2008; Seguy & Buchet, 2013:9). The Rostock Manifesto was written after a series of workshops in the city of Rostock, hosted by The Max Planck Institute for Demographic Research. The people invited to the workshop were all experts in demographical profiles from skeletal data and the aim for the workshop was to develop biostatistical methods and to evaluate and find common techniques for adult ageing (Hoppa & Vaupel, 2002:1). The Manifesto resulted in four components: The first element stresses the need for better osteological ageing methods and the following three involves development and better use of statistical and mathematical methods (Hoppa & Vaupel, 2002:2-3; Knudson & Stojanowski, 2008). The method proposed to use for ageing was TA 2 (Boldsen et al., 2002:73).

2. Background

2.1 Paleodemographic history

Historically, researchers have used ethnographic studies to better understand how past cultures lived and evolved, however this can never be representative for extinct populations (Gurven & Kaplan, 2007; Page & French, 2019). Séguy et al. (2008:84) proclaims the impossibility of recontructing complex and dynamic past populations by only having static material to work with. Therefore, all paleodemographic research should be considered within a margin of error. When putting factors as births, deaths and migration to use, population growth is one of the demographic measures than can be estimated. The population growth, or natural increase in a population, is simply calculated by taking the birth rate minus the death rate. The math thus far is as simple as it gets. The difficulty lies within extracting the basic values for number of births and deaths (McFadden & Oxenham, 2018). Though there will never be two identical individuals, it is possible to between populations draw conclusions of differences and similarites by extracting value means within the population. Such comparisons are often made for life expectancy. For modern populations, the global life expectancy was in the beginning of the 3rd millenium 66 years of age, although, the scale varied from 39 years in Zambia to 82 years in Japan. Life expectancy can thus change rapidly, depending on ”simple” factors such as access to certain health care or an event of a natural disaster. In contrast to modern quite extensive life expectancy, publications from the mid 1970’s and early 1980’s, reported that Paleolithic mean age-at-death was believed to have been 15-20 years and that that was the reality for thousands of Paleolithic generations. The prehistoric site of Libben in current Ohio, USA has been held as a classic example of prehistoric demography. The Libben site was excavated in 1967-68 and revealed astoundingly high mortality rates in the population. The life expectancy at birth was 20 years and as mortality already was high, it was consistently higher for men than for women, which was believed to be connected to interpersonal conflict. Child mortality however was relatively low, resulting in a population with high fertility and high mortality ultimately leading to high workload and a system without grandparents (Lovejoy et al., 1977). Questions were later raised by Howell (1982) if these results might be effects of methodological circumstances regarding age estimation and/or the establishing of life tables of the Libben population. The authors have since acknowledged the criticism regarding life tables and adding the factor of intrinsic growth. Methodology for assessing age was also standardized and limited to a single trait method and fertility rates were revised based on ethnographic studies. Mortality profiles and age structures of the Libben site was also adjusted to reflect growth. The results from these adjustments were that age assessments increased in general, up to 5 years in certain individuals. Even though the paleodemography of Libben was recalculated and reinterpreted, it still remains unique and presents a struggling image of prehistoric hunter-gatherers in Northern Ohio (Meindl et al., 2008).

The Grandmother Hypothesis is a theory connected to the demography of past populations that suggests that post-reproductive life span increased as it provided inclusive fitness benefits for both the grandmother, the daughter and subsequently, the grandchildren. The hypothesis displays effects on fertility, in that mothers are often more prone to having more children if the grandmother is alive and provides changes in mortality patterns due to the fact that elderly women with grandchildren live longer. Senescence and a long post-reproductive life span are believed to have been a result from this (Engelhardt et al., 2019).

Research on modal age in different populations from different time periods has been conducted in order to detect evolutionary patterns. By comparing populatory mortality rates it is clear that these rates have decreased extensively the last century and decreases with about 3 months every year. To visualize this further, the time it took for the average hominin to increase their life expectancy by 10 years was around 1.3 million years whereas the same increase in life expectancy for the average 15 year-old from 1900 CE and onward only took 30 years. Mean age for hunter-gatherers has been calculated to 31 years (ranging from 21-37 years), Swedish people during the 19th century were 32; Swedish people during the 20th century 52 and modern Swedish people reach an impressive age of 82 years old. The life expectancy has accordingly increased 165 % from hunter-gatherers to modern Swedes. These drastic changes in evolutionary patterns however, are not signs of revolutionary genetic adaptation. On the contrary, they are rather effects of a rapid shift in environment (Burger et al., 2012). This also indicates that humans, given favorable environmental circumstances, probably have had the ability of reaching high ages even before the 20th century CE. When investigating longevity, the general hypothesis is that modern humans live for approximately 70 years. Women are normally fertile between the ages of 15-50 years and after that, have a couple of decades of life for assisting in caring for grandchildren (Kelly, 2013:200). Along with menopause, estrogen stops producing and as a result, women can get health related issues such as osteoporosis which make them more brittle and prone to fracturing. The result of the medicinal development during the last couple of decades has made the general population live longer and the menopausal period that was initially a couple of decades have now almost doubled in many parts of the world, leaving a high percentage of brittle, elderly people that instead of helping with grandchildren, often are in prolonged need of help themselves. And instead of being fertile for about half their lives, now that number has gone down to a third. It is believed that the concepts of larger brains, increased longevity, marriage, male investment in offspring, long child dependency on parents and a system of grandparental support are all remnants of the ages before agriculture (Gurven & Kaplan, 2007).

2.2 Not to be confused with Archeological Demography

Archaeological demography is related to paleodemography but instead investigates the structure and dynamics of past populations by using the material culture as its source. Historically, archeological demographers tend to steer their research towards cultural change and diversity, while paleodemography tends to focus more on scientific concerns (Chamberlain, 2009; DeWitte, 2018). However, archaeological demography has in the recent years undergone a similar methodological evolution as paleodemography and is focusing more and more on scientific methodology, especially radiocarbon dating, in order to understand ancient demographic changes (Lechterbecket al., 2014).

2.3 Paleodemographic methodology

2.3.1 Assessing sex

When assessing sex in ancient individuals, it is only biological sex that is possible to determine. Without written sources, it is impossible to make any assumptions about gender and in cases where sex indicating traits are inconclusive or missing, assessments usually assigns the individual an unknown or ambiguous sex. The most reliable methods for assessing biological sex based on skeletal remains uses the os coxae to investigate dimorphic traits. The traits on the adult pelvic bone are clearly differential for women and men due to childbearing factors. However, if the pelvic bone is damaged, dissolved or not present, there are few reliable traits that can be used. Often, all bones that might show dimorphic traits are assessed and a mean value is calculated, and an individual is assessed as male, female or undetermined. In some cases, additional categories of probably male/female also exist (Buikstra & Ubelaker, 1994; Monge & Mann, 2015). However, morphological evolution of the skeleton is constant and the more ancient a skeleton is, the more it differs morphologically to modern equivalents. Traits that indicate biological sex in historical and modern skeletons are not necessarily indicative of the same in ancient skeletons. The purpose of distinguishing biological sex in individuals when conducting paleodemographic research is to extract the variable of female mortality for the fertility related structure of a population (Monge & Mann, 2015). Juvenile individuals do not display the traits in question and should therefore not be sexed, but regarded as one entity (Séguy & Buchet, 2013:33).

The methods used in this study for assessing the biological sex of an individual are based on traits located in the pelvic bone and are described in Buikstra & Ubelaker (1994). It is also possible, however not as accurate, to use osteometry to determine biological sex. The main principle is to measure the bones that normally are the most sexually dimorphic in order to establish a binary and relational division to observe the spread of dimorphism. The smallest individuals can be seperated from the largest in a population and results have indicated that this method has the possibility of establishing biological sex in 80-90 % in validation studies (White, 2011: 415).

2.3.1.1 Scientific analyses

Although being a relatively young branch of science, the use of isotopic and genome sequencing analysis have already been called the Third Science Revolution of Archaeology (Kristiansen, 2014). The isotopic analyses are foremost important for investigating the health and mobility of a person while genome studies can reveal more about origin, sex and genetic prerequisites (Sverrisdottir et al., 2014). DNA studies can aid in determining biological sex in individuals were the sex indicating bone markers are missing. Recent studies on tooth enamel have shown that it is possible to extract protein called amelogenin. The protein binds to both x-chromosomes and y-chromosomes, but is presented slightly differently. This method could be groundbreaking in sex determination, especially in ancient and often poorly preserved material, and also when assessing sex in juveniles (Stewart et al., 2017).

2.3.2 Assessing age

2.3.2.1 In juveniles

The traditional methods for ageing infant and juvenile individuals are quite established and accepted in the scholarly realm. Dental eruptions and developments, as well as epiphyseal fusions are frequently used and althought may differ, mostly follow similar patterns and have a marginal of a couple of months or years faulty depending on what age is assessed (Baitzel & Goldstein, 2016). It has though been observed that general fusion in juveniles have been pushed forward somewhat and that ossification occured earlier in past populations but also that ossification can occur at different times for different populations (Séguy & Buchet, 2013:35). This can also be connected to Life History Theory where one of the pillars includes reproductional investment. The plasticity of developing humans enables us to distribute energy where it is most needed due to positive secular growth trends. This investment is usually divided between either fertility or growth and is visible in the osteological material on a populatory stage (Langley-Shirley & Jantz, 2010).

2.3.2.2 In adults

When assessing age in adults, there are several age specific traits that can be used such as the closure of cranial sutures, morphological changes in the pubic bone and the auricular surface of the iliac bone (Kemkes-Grottenthaler, 2002:48; Bullock et al., 2013; Getz, 2017:13). Also, costochondral joints and dental wear can provide indications of a person's age-at-death (Kemkes-Grottenthaler, 2002:48; Meindl & Russel, 2018). When age-at-death is to be assessed there are several methods that have been and can be used, all of which have recieved their fair share of critique. Traditional osteological ageing methods are well known for systematically producing errors in it's estimations of older adults (Bocquet-Appel & Masset, 1982; Buikstra & Koningsberg, 1985; Meindl & Russell, 1998; Boldsen et al., 2002:75; Hoppa, 2002:11; Signoli et al., 2002; Eshed et al., 2004; DeWitte, 2006:36; Jackes & Meiklejohn, 2008:210; Caussinus & Courgeau, 2010; Roksandic & Armstrong, 2011; Bullock et al., 2013; Séguy & Buchet, 2013:39; Clark et al., 2019). The methods are consistently underageing individuals of older adulthood and are negatively affected by degenerative changes, something that generally increases with age (Bullock et al., 2013). It is not only the accuracy that decreases with ageing older adults that is the problem, but also the age ranges increases meaning that the variability is much greater and can sometimes produce age ranges decades apart. The methods have also proven to over-age younger adults and results are often presented with disclaming remarks (Bullock et al., 2013; Clark et al., 2019). One of the main reasons for producing faulty age estimates is that of age mimicry, meaning that the estimates are based upon reference material and is often seen as an artifact of that material. It is therefore difficult to determine if the estimates are valid for the studied population or simply mirrors those of the reference population (Koningsberg & Frankenberg, 2002;

Clark et al. 2019). Morphological evolution have also been proven to occur, only in the last century, cranial sutures have been known to ossify earlier and earlier in life, making historic or even pre-historic comparisons unreliable (Bouquet-Appel & Masset, 1981). Buikstra & Koningsberg (1985), on the other hand, argues that the shortcomings of the use of life tables or osteological standards are results of misuse of the methods. Getz (2017:7, 12) presents three fundamental assumptions that all skeleton age-assessing methods needs to rely on: firstly, skeleton variation needs to be identified and classified in the same way by anyone, secondly, the traits which the assessments rests upon needs to correlate with the passing of time in a predictable way, and thirdly, the changes in features needs to be relevant and inclusive for all people, not depending on sex, time or geography and be mindful of anatomic variation.

2.3.3 Transition Analysis

There are a variety of statistical methods that have been used in paleodemographic research. Transition Analysis has been used more frequently during the last couple of decades in paleodemography. The first and second versions of TA were based on Bayesian theory that calculates the probability for reaching certain age stages, however the third version instead works with machine learning, a technique using Artificial Intelligence where the computer learn from the data it processes (Boldsen et al., 2002:73; Knudson & Stojanowski, 2008; Caussinus & Courgeau, 2010; Bullock et al., 2013; Vieira et al., 2019). This also avoids the well-known problem of age mimicry since the data is not based on reference material.

The effect and main advantage of the method is the ability to better assess age in older individuals. TA has been reformed twice so far and the most recent version is TA3, which is less reliant on age indicating traits on the pelvic bone than the previous version (Getz, 2017:46). The pelvic bone is often damaged due to its exposed position in the skeleton. For the third version of TA, definitions were revised and the number of categories was reduced and the method adjusted in order to better include populations from different parts of the world and also modern populations in order to be used in forensic anthropology (Getz, 2017:45-46). Although TA3 is the most recent version, when addressing TA in previous studies in this assignment, it is the previous versions of

TA that is referred to due to the relative freshness of the third version. The third version is however the one used in this study. The general idea of the TA method is to collect age information from various part of the skeleton and based on these collected traits, estimates an age for the individual, but can also be used for single bone elements, however this will prove less accurate (Boldsen et al., 2002:88-89). The method is believed by Knudson & Stojanowski (2008) to eventually replace the traditional ones. However, degenerative changes in bones can affect the assessment and produce faulty results between populations (Bullock et al., 2013). The difficulties with using TA2 focus on the credibility of the method and results most often differ significantly from those of traditional methods. Clark et al. (2019) however, proposes a number of precautions when using TA2 and suggests that the bioarchaeologist should not rely on a single ageing method, include age-at-death distributions derived both from TA2 and traditional methods and be very clear on the impact of the chosen method when drawing conclusions from the data. The creators of the method, Milner & Boldsen (2012), gladly proclaims the advantages of the method, as one would imagine, however, also strongly advocates for collected experience-based assessment as the undefeated method for age estimation in skeletal material.

Although there are several different methods used for assessing age, none of them has been proven to correctly assess ages beyond 50 years of age. The methods that claim to be able to do so have been proven the contrary at multiple occasions. So historically, if people did not live past 50 years of age, there is no problem, however, if they in fact did live past 50 years of age, there is no way of detecting these individuals and all previous paleodemographic based on traditional age assessment methods needs to be reevaluated. Our understanding of how past individual lives was lead, how societies were composited and functioned and how the rates of mortality probably are misinformed (Gertz, 2017:1-2). The two most reliable methods in traditional age assessment are based on cranial sutures and the pelvic joints. Both of which do not display any significant change after an individual reaches 50 years of age. The cranial suture based method has in addition been proven to not be a reliable indication of age as previous research has showed. There is only little correlation, with an emphasis on little, between suture closure and age-specific information up to a maximum of 40 years (Milner & Boldsen, 2012). The sacroiliac joint is the least reliable age indicator of the pelvis and can only be used up until an individual reaches middle age. The most reliable age indicative feature on the pelvis is the pubic symphysis, however its location on the skeleton often makes it exposed to archaeothanatological events and is often damaged (Milner & Boldsen, 2012). The TA method was developed because of the need at hand to properly assess ages for older adult individuals in order to produce reliable and reasonable paleodemographic data. TA2 is inclusive for ages between 15-105 years of age and has been tested on human remains of different periods in time and from various global populations. Since the development of the method has undergone much more inclusive testing than previous methods that rather is based on referenced material and consequently age mimicry, TA has the possibility of providing a much requested reliable variable in archaeological research (Gertz, 2017:2). Also, because the method has been tested on several different skeletal collections showing promising results, it is much more inclusive for global use, however, this inclusiveness has resulted in less precise age estimates (Getz, 2017:7).

The benefits of using traditional methods include the accessability of the method in question. They are often easily applicated and user-friendly with a gradiant development or morphosis scale. TA1 initially had around 100 possible traits that could be identified on different scales, making the method unaccessable compared to standard ones. The second version had 33 possible traits, all of which located to the skull and pelvis (Milner & Boldsen, 2002). The new version have 62 traits and a binary variable resulting in an easily applied model as well as less focus on cranial sutures and pelvic traits (Getz, 2017:4; Milner & Boldsen, 2002). The method provides the inclusion of traits from throughout the skeleton that is able to contribute with information similar to that of a skilled osteologist (Getz, 2017:4).

2.3.4 Statistical methods

A method useful for the study of mortality that has been widely used in paleodemography is the application of life tables. Life table method is a statistical method that investigates longevity and operates by calculating the probability for the death of a person before that person's next birthday. A life table can be created as a static table or a cohort table, depending on what information needs to be extracted from it and are produced for populations based on previous known related material. The composition of a life table is based on osteological data extracted from traditional methods and regression analysis and is especially useful for comparing mean ages in different populations (Eshed et al., 2004). Wood et al. (2002:129-130) recognizes two issues with the use of life tables; First, the standard methods does not produce relevant data needed to calcute mortality rates, and secondly, assumes that the studied population was static and that there was no activity in migration or intrinsic rates, and that fertility and mortility was rigid. There have been discussions about whether life tables should be corrected for population growth or not in order to adjust to cohort changes. However, prominent scientists have argued that a correction is unnecessary because of the long term population growth in humans have for most part of human history been nearly 0 (Roksandic & Armstrong, 2011). There is also a big uncertainty concerning which life table to use in what context, making the method occationally difficult to apply (DeWitte, 2006:35; Séguy et al., 2008:85). Luy & Wittwer-Backofen (2008:121) stresses the problematic character of the use of life tables by mentioning the often misleading interpretations made when fertility and population growth are not included or considered. However, life tables can under special circumstances and preconditions be useful for depicting mortality patterns in past populations. Lynnerup (1996) in his study used a combination of deterministic and stochastic approach when calculating the paleodemography of Greenland. The deterministic models are based on the assumption that population growth is expressed as a function and is exponential and linear. The stochastic models involve the element of chance and are event-based. Too many events can eventually lead to the extinction of a population. By combing these two, it is possible to roughly calculate real events and evolvements in a population and detect it's carrying capacities and tipping-points. Ahlström (2015:14) in his study of current Scanian and Gotland ancient populations uses the Siler competing hazard model (Siler, 1979, 1983) and Average Forager Model (AFM) (Burger et al., 2012) when calculating human mortality. The Siler model uses three components that might constitute hazards during different periods of life (DeWitte, 2006:66). The AFM is based on data from ethnographic studies of modern reference populations of foragers, along with studies of chimpanzees.

2.3.5 Classification systems

When individuals have been aged, osteologically or statistically, they are often placed in age groups. These age groups vary heavily depending on the hypothesis or the results from the ageing process itself. These groups are often multivariable and divided into numerical or categorical cohorts, such as or 5 year age-gaps or *Infant-Senilis* age groups. The aim for this method has been to identify stages in a person's life rather than making point age estimates that due to differences in ageing methodology may vary greatly. The age-at death profiling has thus recieved criticism for not being overall statistically significant, inclusive and reproduceable due to its variability and adaptability (Hoppa, 2002:10; Roksandic & Armstrong, 2011; Suby et al., 2017).

2.4 Paleodemography in Medieval Denmark

Table 1. Age distribution at Löddeköpinge cemetery

Age group	Mortality rate
Juvenilis (15-19 y)	9 %
Adultus (20-39 y)	44 %
Maturus (40-59 y)	39 %
Senilis (60+ y)	8 %

Between 1975-1980, an Early Medieval cemetery was excavated in Löddeköpinge. The town of Löddeköpinge is situated in the province of Scania, between Lund and Landskrona, all of which fell under Danish reign during most parts of the Middle Ages. The Löddeköpinge cemetery has been dated to the years around 1000-1150/1200 CE and contained 1 412 graves (Cinthio, 1988:121, 125; Boldsen, 1990:182). Sex was determined for 679 (65 %) of the individuals and roughly 1/3 of the buried population were children by the age of 10 years and younger. The amount of assessed men was 359, while 320 individuals represented women. Age assessment was conducted for 764 of the total population and the individuals were then placed in age groups accordingly. The results from these mortality proportions indicate high mortality in young adult as well as middle age adult individuals (Iregren, 1988:39, 45). The results of the paleodemographic study of Löddeköpinge produced the estimation of a population consisting of approximately 500 individuals. Arcini (1999) conducted an extensive study of buried individuals from Medieval Lund wich then was part of the Danish Kingdom. In total, 3 576 graves from three cemetaries was examined. The cemetaries in question were active between 990-1536 CE (Arcini, 1999:48). The skeletons were assessed for age and biological sex by using traditional methods. For age estimation, craniosutural closure, changes in the pubic symphysis and dental wear were used for adults. The development of bones and teeth as well as epiphyseal fusion was used for children and juvenile individuals. The individuals were then placed in age groups as follows: *Fetus* (0-9 months), *Infant* (0 y), *Infans* I (1-6 y), *Infans* II (7-14 y), *Juvenilis* (15-19 y), *Adultus* (20-39 y), *Maturus* (40-59 y), *Senilis* (60+ y) and Incomplete skeletons not able to be determined other than ”adult” (*20+ y*) (Arcini, 1999:52). Estimation for biological sex was based on primary and secondary traits on the pelvis, crania and sizes of the humeral head, femoral head and femoral condyle. Out of the over 3 000 examined skeletons, 1 039 was assessed as subadult and 1 537 was estimated as adults. In total, 77.9 % of the material was well preserved enough for age estimate analysis. Unfortunately, for 20 % of the skeletons, it was only possible to assess an age of at least 20 years making age distribution unprecise. When the *20+* category is excluded, age-at-death distribution for adult individuals in Medieval Lund are 20-39 years for 65.4 %, 40-59 years for 27.6 % and 60+ years for 7 % (Arcini, 1999:160). Mortality estimations were conducted for juveniles/adults as well as for children. The mortality rates increases with chronological periods in both groups with the lowest rates in the oldest material and highest in the youngest material (Arcini, 1999:55). Biological sex was determined in 67-93 % of the skeletons, depending on cemetery and time period. More men than women were assessed in that 57.6 % were estimated to have been male and 42.4 % to be female. Arcini (1999:57-61) also compares the studied material to archaeologically retrieved skeletal and published material from contemporary cemetaries in current Scania and Denmark. The compared material consisted in 4 202 individuals from ten cemetaries and parishes. What becomes clear when comparing the materials is that infant mortality seems to be higher, up to 60-67 % in certain parishes. For children in the *Infans I* category, the mortality rates are similar (Arcini, 1999:57). However, S: t Mikael stone church stands out as two thirds of all unhumations belong to infants and children up to 6 years of age. Regarding overall mortality rates for juveniles/adult and children, the compared material matches the studied material as mortality increase with chronological time periods (Arcini, 1999:59).

For the *Adultus* group, mortality was higher in the studied material than in the compared and for the *Maturus* group, rates were similar, as was rates for the *Senilis* group (Arcini, 1999:57). Biological sex was able to be determined in 84 % of the adult material in favor of male assessment with 44.1 % versus female 39.6 % (Arcini, 1999:161). Arcini (1999:62) points out the frequent problem with representativity in Medieval skeletal material since cemetaries often are found within cities and never so often excavated entirely and is often disturbed by both historic and modern constructions.

2.4.1 S: t Nicolai cemetery

The Middle Ages in Scandinavia covers the period from the end of the Viking age in the second half of the 11th century until the Reformation in the first half of the 16th century. During most of this period, Scania belonged to the Danish Kingdom along with parts of Blekinge and Halland. The north eastern parts of Scania was known since the Viking Age for it's rich fertile soils where live stock was kept and bred on the large moraine clay heaths (Wihlborg, 1984:44-45). Helsingborg is first mentioned in Adam of Bremen's chronicle in the end of the 11th century CE, but is then called *Halsinburg*. A few years later, in 1085 CE, Helsingborg is for the first time called a town by the Danish monarch Canute the Holy and a tax of the lands of the town is first introduced. The occurence of taxating is synonym with the area being regarded as a town (Hök & Kindström, 2005:14). During the following five centuries of Danish reign, Helsingborg is rebuilt and fortified several times because of the constant oppositions both within the Kingdom as well as from abroad. From about the time of 1050 CE, three churches were established on top of the abrasion hill Landborgen that forms a natural fortification. These churches along with its cemetaries were active throughout the Middle Ages. In the year of 1269 the Dominican Order founded the S: t Nicolai convent in vicinity to the other churches and is believed to have been finished in 1275 (Johannesson & Bååth, 1933:303; Arcini, 2020:80). The Dominican order is also known as the Beggars' order where the members were urged to wander instead of staying at a certain monestary for *ora et labora*, and thereto called on to beg for their livelihood. The Dominican order was along with other Medicant orders established for the poor and liable people who had difficulties paying the feudal taxes in and between the recurring famines that struck Europe during the Early Middle Ages (Kilström, 1976:9f). Poor and exposed people did not only live in

Helsingborg and so the Dominicans founded additional contemporary convents in Scania, Denmark, southern Medieval Sweden and Åbo (Johannesson & Bååth, 1933:304-305). S: t Nicolai convent got its name from a canonized Greek bishop known for his generosity toward those in need. He has since become the patron saint for children, sailors, thieves, prostitutes and the unmarried but is today more known as Santa Claus (English, 2018:2-3). The convent was established in current Kv. Minerva, situated between Bergaliden and Drottning Margareta's road. The convent was demolished together with all churches and convents belonging to Medicant orders in 1556 after a long period of secularization and a final decree from 1537 CE stating that ownership of all convents including inventory belonged to the king (Johannesson & Bååth, 1933:315). It has been proven to be hard to interpret how the convent might have been designed. The church probably had a polygonal chancel that at some point was extented westward. The main building was probably double aisled nave with its side-isles towards north. The adjacent Dominican complexes were placed south of the church as well as along the wall of the south nave (Cinthio, 1989:95-97).

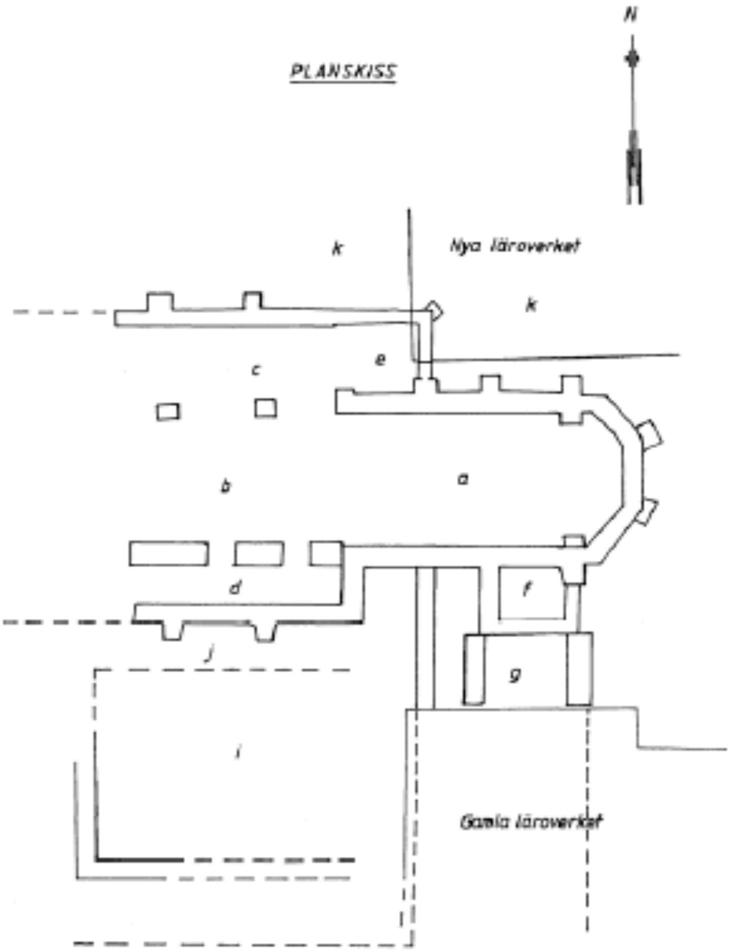

Fig 1. Drawing of the known outlines of the S: t Nicolai convent (Hök & Kindström, 2005:18)

Even though the Dominican orientation leaned towards the poor, the burial plots needed to be purchased and were therefore designated for the people who were wealthy enough. The individuals at the S: t Nicolai cemetery were buried either in coffin, on planks or directly on the ground in pits. Some of the graves were strewn with lime, as was a common burial practice during the Middle Ages, along with depositing the buried on top of a bed of charcoal. As time goes by and approaches the Black Death in 1350 CE, the amount of single graves decreases and instead, double and tripple graves increases in all cemeteries in Helsingborg (Arcini, 2020:80-82).

The material from S: t Nicolai cemetery was excavated between 1952-1954 since the city council decided to expand the then existing *Gossläroverket*, (educational institution for boys). *Gossläroverket* has since the 1950's been rebuilt and today the site is occupied by a high school called *Nicolaiskolan*. As can be seen from Fig 1, the full extent of the convent is unknown, the solid lines represents confirmed contructions and the dashed lines represents likely constructions, however further constructional outlines are unknown due to later disturbances. The material was hastly exhumed and poorly documented. The exhumed individuals were later transported between storage facilities in wooden Martini Rosso-cases and at the time for the finalization of the archaeological report in 1999, the skeletons were still stored at Lund University Historical Museum's (LUHM) storage facility in Hög outside Löddeköpinge (Hök & Kindström, 2005:13; Gunnar Dahlgren, personal communication, Feb 2021). The rapport was written by initiative of the Helsingborg city museums' employee Happy Hök along with the original 1952 excavation leader, Lars-Göran Kindström. Lars-Göran Kindström discloses in the report that the documentation as well as findings have been misplaced, lost and jumbled over time and that the information and material should be approached with this in mind (Hök & Kindström, 2005:37). The archaeological report was published in 2005 and at around that time, the skeletal material was again moved from LUHM's storage in Hög to Helsingborgs museums' storage at Kulturmagasinet in Helsingborg. Before the bones was transported, they were transferred to acid-free card board boxes which was also the state of the skeletons when they were investigated for the purpose of the imposed study (Gunnar Dahlgren, personal communication, Feb 2021).

2. 5 Research history

A comparative study published in 2008 but executed in 2003, tested a variety of age assessment methods in order to detect differences when examining exhumed individuals from an Early Medieval cemetery in current Germany. The cemetery was in use from the 6th until the 12th centuries CE. In total, 121 individuals was examined by 13 observers with extensive documented experience using complex multimethod approaches, Transition Analysis 2, craniosutural ostosis, auricular surface assessment, osteon density method, tooth root translucency measurement, and tooth cementum annulation counting (Wittwer-Backofen et al., 2008). Since the material did not provide any pre-known ages, it was not possible to determine the better or more accurate method; the purpose was rather to detect differences in methodology. Assessment of biological sex was determined by using standard methodology as well as grave goods. Only skeletons presenting with secure sex estimates were included and 54 men and 62 women was identified in the material. Some of the methods, such as the multivariate and TA2 could in many cases only provide a minimum age and not a maximum making extracting of a mean difficult. Four of the graves were selected for comparison since the conditions for age estimation was representative of the entity of the material. However, these four graves had vastly different results from the different age estimate methods. Even though the skeletons presented with somewhat complete material, the estmates still spanned from 25-55 years, 25-45 years, 35-60 years and even 20-105 years of age-at-death. The single-trait methods had lower correlation with all other methods than the multi-trait methods. The results showed that the overall high overlapping age assessments occured in young adult individuals whereas the low overlapping mainly included ages 40-60 years of age. TA2 and the other tested multivariate aging methods produced systematically older ages than the other methods. These methods, along with the single-trait method based on the auricular surface also provided the overall most overlapping results with other methods and also provided the biggest age-ranges. The results indicate that these methods provide the most inclusive criterias. The study also showed that older ages often were indicated by suture closure, something that has been proven to be an unreliable trait. The study concluded that the methods produced great variance in results and that multi-trait methods are better suited for age assessment than single-trait methods. However, the multi-trait methods used in the study were in need of revision in order to correct methodological weeknesses such as slimming age spans, reduce errors and improve older age assessments (Wittwer-Backofen et al., 2008). This study was conducted in 2003, one year after the Rostock Manifesto was published as a call for better age assessment tools. The Transition Analysis 2 was still a new method and this study pointed out very valuble factors in its development. The method has since then been revised twice in order to minimize errors and better produce accurate age estimates.

Gurven & Kaplan (2007) presented a study on demographic data from extant hunter-gatherer populations ranging from the 1930's CE and onward. The populations have had minimal contact with modern medicine, horticultural methods and any type of crop or plant capitalism. Althought the populations are spread all over the world and have different approaches to their ”primitivism”, the authors have observed significant collective demographic indicators for the groups. Over two-thirds of people survive unto grand-parental age and prolong for an average of 20 years. Mortality rates are low and stable until reaching an age of about 40 years old, after that, mortality increases exponentially for about a decade. The average adult age-at death is 72 years. Earlier ethnographic studies of longevity displaying low child and high adult mortality are most likely affected by exposure to infections, violence and poor methodological age estimations. All samples studied indicate causes of death to account 70 % to infectious disease, violence and accidents to 20 % and degenerative diseases to 9 % (Gurven & Kaplan, 2007).

A study by Jackes & Mieklejohn (2008:226) investigated paleodemography in a late Mesolithic Portugese population and used life tables for their analysis. The life table was divided into 5-year groups from the years 0-25 and ended with a compiling group for all people 25 years and older. They also had difficulties identifiying children belonging to the first age group, 0-5 years, ultimately deciding to exclude them entirely.

Simalcsik et al. (2013) studied the paleodemography of a medieval population exhumed in current Moldova. The cemetery was situated in the village of Lozova and belonged to the 14th-15th centuries CE. The data recovered from the buried individuals were then compared to data from two similar populations of Brăila and Hudum. The Brăila cemetery has been dated to the 15th century CE and the Hudum cemetery has been dated to the 13th-15th centuries CE. The population from Lozova cemetery displayed high mortality in children and juvenile individuals and less than two thirds of the entire population lived past 20 years of age. Mortality in the adult cohort was 17.6 % and when it came to the mature part of the population, the mortality rate reached 43.1 %. No one past the age of 60 years of age could be identified in the material. When calculating life expectancy, the rate from birth was 27.23 years. For those surviving past the age of 20, life expectancy was additionally 25.5 years for both female and male individuals. The mean age when death occured was 36.5 years for the adult population for men and 42 years for women. The source material included a higher ratio of male individuals. It should be mentioned that the total amount of individuals exhumed and investigated was quite small with 51 skeletons. The taphonomic preconditions of the material were good in about 50 % of the material wich constituted great opportunities for thorough osteological analyses. The aging of the juvenile individuals were conducted using dental eruption and fusing of epiphyseal ends in long bones. The aging in adult individuals was based on examinations of the pubic symphysis and degenerative sacroiliac joint development. Also, spongious long bone tissue, skeletal involution, dental masticatory wear and synostosis of cranial sutures were studied in order to assess age in the adult population. Sex was determined using the standard assessment methods of the pelvis and crania as well as shape and size of the teeth (Simalcsik et al., 2013). Mortality rates for children and juvenile individuals in Brăila have been calculated to be 15.63 % and 44.51 % for the same group in Hudum. Mortality rates for the adult cohorts in Brăila and Hudum respectively were 15.6 % and 28.7 %. Mortality rates for mature populations at both sites were 62.5 % in Brăila and 7.92 % in Hudum. The only site of the three presented with any individuals surviving past 60 years of age, consequently belonging to the senile cohort was found at Hudum cemetery where the individuals constituted 3 % of the exhumed population. The distribution of biological sex differed between the sites. At Lozova there were 22 men and 13 women identified. At Brăila the ratio was more even, identifying 14 men and 15 women. At Hudum, the distribution again indicated domination of male presence with 27 identified men and 13 women, however, overall, many of the women at all three sites survived past the adult stage and reached mature age. The life expectancy at birth for the Brăila population was 36.8 years while only

16.99 years for the Hudum cemetery. The mean age of death at both Lozova and Brăila populations was calculated to about 40 years of age whereas the same rate for the Hudum population was only 31.88 years. This study indicates that Hudum cemetery, wich was also the youngest, displayed significantly higher mortality rates in children, juveniles and young adult individuals and the average age at death was significantly lower than the other two sites belonging to later Medieval periods (Simalcsik et al., 2013). However, all of the examined individuals displayed arm positionings C and D, suggesting either geographical variation or that the burials took place during the time of the Medieval decline. Only parts of all three cemetaries were excavated, suggesting that the distribution of the buried individuals might be skewed and does not represent the entity of the population.

DeWitte (2015) investigated survival and mortality rates in two separate pre-Black Death populations in London. The epidemic resulted in tens of millions of deaths throughout the world's population, however the reasons for such high mortality rates are unclear. DeWitte (2015) theorizes on reduced health and stress as being part of the low resistance in these populations resulting in low resilience against the *Yersinia pestis* bacteria. A major cause for a reduction in health and induced stress are repeated famines, which have been reported to affect the English Kingdom during the 14th century. The two studied populations derive from the 11-12th and 13th centuries CE respectively. The goal was to find out if the health of Early and High Medieval Londoners was declining even before the Black Death occurred. Over 1 000 skeletons were examined from the two cemetaries and mortality and survivorship was calculated using statistical methods Kaplan-Meier survival analysis as well as Gompertz hazard of adult mortality (Gompertz, 1825). The selection of graves was based on Bayesian carbon dating and was carefully chosen not to overlap Black Death burials. Age assessment was conducted by using transition analysis. Biological sex was not assessed as mortality, fertility and survivorship was based solely on age distribution in the total populations. The distributions however indicated that there was a significant difference between the two cemetaries where older adult individuals were harder to detect in the material from the 13th century. Survival analysis also suggested lower survival rates of the 13th century population than the older one. Hazard analysis further confirmed declining populatory health as mortality rates for the 13th century population increased compared to the 11-12th centuries population. People in London pre-Black Death had declining health leading to lower resiliance against disease. Whether the health recession was a result from repeated famine was not confirmed, however, DeWitte (2015) stresses the importance of recognizing human context to understanding both past and now living human populations. By including life course theory, results from scientific and statistical data collection can be integrated with social anthropology in order to understand social identities.

Baitzel & Goldstein (2016) examined the remains from a Peruvian hunter-gatherer cemetery and found that there was an overall absence of adult individuals buried there. Factors like taphonomy, poor archaeological sampling or looting was written off as contributing factors. In the sample, the statistical analyses pointed towards social causes rather than biological ones. This was interpreted as a result of return migration during adulthood towards some kind of corresponding homeland. Bullock et al. (2013) compared ageing methods when examining post-classic populations from current Mexico. When comparing traditional methods to TA2, the age distribution varied heavily. The traditional methods displayed high young mortality with few individuals living past the age of 50 years old. TA2, on the other hand, indicated that the majority of the buried population lived past 50 years, thus demonstrating low mortality for young adults. Clark et al. (2019) similarly compared traditional methods to TA2 on prehistoric human skeletal remains from current USA. The results corresponded to those of Bullock et al. (2013). The ageing of older individuals increased and so did the longevital survival curves created from the studies. The authors refrained from drawing conclusions from the results and recommended that both ageing methods should be used in future studies until TA2 has become more scientifically established since the results differ extensively between methods.

Suby et al. (2017) investigated skeletal remains from ancient hunter-gatherers in current southern Patagonia. They found that the infant and child mortality was very low whereas the mortality for people between the ages of 20-50 years old was very high. The low child mortality could be affected by taphonomy and morturary practices and the high mortality for adults could be affected by the use of traditional ageing methods.

3. Theories

3.1 The Osteological paradox

In 1992, Wood et al. presented a group of key concepts for understanding correlations between health and death. The concepts were selective mortality, demographic nonstationarity and hidden heterogeneity in risks and together they made up what was called the Osteological Paradox. Selective mortality can roughly be translated to ”what we see is what they got”. The death of individuals at certain ages might not reflect risks for the population as a whole, since other individuals obviously survived and died of other factors later in life. To calculate hazard for younger dead individuals is therefore biased. Unfortunately, the problem with selective mortality is unavoidable but still needs to be adressed and taken into consideration when it comes to analytical purposes. Demographic nonstationarity means the unreasonability of static populations. It is impossible for any population to remain completely closed from outside migration or to have constant fertility and mortility rates, and the dynamic of paledemographic processes therefore needs to be included in all osteological analyses. Hidden heterogeneity in risks mean that even though the study involves populations, there needs to be awareness of the fact that there is a great span of individual variability for frailty and proneness for disease within that population. The variability can come from genetic factors, socioeconomic prerequisites or from microenvironmental shifts in diet or health trends (Wood et al., 1992).

The Osteological paradox permeates the osteological analysis and needs to be taken into consideration when investigating remains as well as interpreting results. The key premiss of the Osteological Paradox is that the material that osteologists base their knowledge upon is really not representative for health and disease since the material only reflects impaired health and those who did not survive (Wood et al., 1992). Central to the Osteological Paradox is mortality and the presumption of said mortality. The fundamental rule is that the most frail are the first to succumb. Every population therefore contain bias against the corresponding, living and representative population. To base the interpretation of the health of prehistoric populations on the ill creates a skewed image of how reality actually looked like (Wood et al., 1992). Old age in a population is a sign of good health based on the simple fact that people were able to reach that age without dying of various causes such as disease or trauma at a younger age. The phenomenon can also be applied in other contexts, as is the case of the survivorship bias, first mentioned by mathematician Abraham Wald when pointing to damages of returning World War II airplanes. The returning airplanes were covered in damages on specific areas of the plane and mechanics stressed the importance of reinforcing those areas. Wald, on the other hand realized that these planes had survived the attacks and that it was rather neccessary to reinforce those parts of the airplane that had not been damaged because these parts were clearly the vital parts of the function of the airplane (Bermúdez-Guzmán et al., 2020).

3.2 Life Course Theory

Biological anthropology, or the interpretation of human evolution, is based on the study of human skeletal morphology. The science of detecting morphological differences and developments in humans and hominins stems originally from race biology from the 18th and 19th century CE. While some scientists used the theory for soughting out quixotic indications of links between appearance, ability and values, others used the theory for detecting evolutionary development in physical adaptments such as locomotion, dietary shifts and climatary adjustments. Today, the theory is highly relevant, however not with morphological indicators of bones as source material, but instead with molecular and cellular indicators of them (Agarwal, 2016). These new approaches have led to a wider methodology making the field more interdisciplinary. Evolutionary biology is one of these disciplines that look into the skeletal evolution of humans and non-human primates. The morphologies in craniofacial structures as well as postskeletal structures are studied in terms of phylogeny and function to determine development and familiarity. Bioarchaeologists more often study individuals and differences between them rather than larger scale phylogenetic variations. The bioarchaeological studies focuses on what makes individuals or populations different from each other, what makes them stand out and are dependent on factors regarding health, diet and activity. Since the study of paleodemography is based on the correlation between health and society and works as a tool to map the life of an individual, life course theory would be suitably applied. Life course theory focuses on social bioarchaeology that can be visible in the remains of humans in order to detect indications of their social identities

(Knudson & Stojanowski, 2008). Depending on the social circumstances of different populations, various concepts can be applied. One of these concepts concerns populations affected by increased density and sensitivity of illness and has been called disease culture by Fay (2006). Within disease culture, pathology and historical evidence along with osteological analyses can reveal social roles and inequality even within chronic disease cohorts. During periods of extensive and widespread illness, norms are still obtained and hierachy based on social and economic factors are highly relevant within cemetaries of certain pests. In societies where illness is viewed monochronically, chronically ill people are instead staggered and seperated from the illness-free norm.

Genetic studies can provide with large-scale migratory patterning and sex assessment in poorly preserved material as well as reveal rare genetic mutational developments. Now, instead of looking at familiar traits, it is possible to sequence entire DNA-strains in order to find of familiarity, origin and mobility. It is also possible to investigate morbidity and proneness to disease as well as fertility-related factors in both individuals and populations. Health and diet are directly linked to mortality and fertility and indications of states of health and diet can be investigated through osteological studies as well as molecular analyses (Agarwal, 2016).

3.2.1 What effects fertility, mortality and migration?

Events that have the biggest impact on fertility, mortality and migration are war, epidemics and starvation. In small populations, these factors could have huge consequences (Lynnerup, 1996). Developments in isotopic and genetic studies have for the last couple of decades provided archaeology with information that previously would have been impossible to get in any other way. It is now possible to identify migration, health and human kinship and evolution in ancient populations, something that can be very useful for paleodemographers. These are relatively young methods on migration that have recieved heavy critique for oversimplification and generalization in how and why research is performed and can often feed nationalistic ideas of origin and superiority if not executed nor explained properly (Furholt, 2018; McFadden & Oxenham, 2018). When it comes to the effects of migration, the results are contradicting and might be strongly correlated to additional factors other than migratory actions alone (Bullock et al., 2013).

An epidemic or a disaster can be helpful for when determining a past demography during a certain and short period in time. The excavations in Pompeii have provided archaeologists with a unique frozen moment in time and with demographic data for an entire community. Studies have shown that disasters can be observed in archaeological material as an overrepresentation of young individuals (Bullock et al., 2013). Following an acute epidemic disease, the exposed individual either dies or endures (Paine & Boldsen, 2002:175). If they endure, they come out more resilient and strong, which also ties into the core of the osteological paradox (Wood et al., 1992). An epidemic such as the plague could provide similar data due to the fact that many people died within a short period of time. However, epidemics can also distort the image by the illness itself. Signoli et al. (2002) suggests that the Black Death provided a snapshot into age distribution and offers a representative image of the living population before the big outbreak. However, this is partly the case but the fact that certain pests infect certain cohorts differently needs to be taken into consideration. The Black Death is often described in historical sources as having higher morbidity and mortality in young populations (DeWitte, 2006:22-23). The term for this is selective mortality and can also be seen in certain population's practing infantice or selective infanticide and primarily affects fertility (Lee & DeVore, 1968:11; DeWitte, 2006:72; Kelly, 2013: 188; White, 2014). Epidemics have probably had big effects on migration because of an increased need to move to uninfected areas and abandon high-risk environments (DeWitte, 2006:6). The most common factors for mortality are malnutrition, infection and disease, however, determining the cause of death is much harder for these factors than for the less common ones such as homicide or accidents which more often leaves skeletal marks and can therefore produce bias in research that focuses on mortality (Gurven & Kaplan, 2007). Shifts in causes of mortality have also occured, and might have had effects on the populatory fertility. Before modern medicine, infectious disease was the primary cause of death, today, the main causes of death are those that oftenmost needs time to develop, such as cancer or cardiovascular disease (Kelly, 2013:200; Ahlström, 2015:11). In ethnographic studies, there is little or no cardiac disease or cancer detected in primitive populations, connecting these diseases to a sedentary lifestyle (Dunn, 1968:224). An interesting correlation that have been observed by a number of researchers regarding paleodemography is that fertility has proven to have a greater impact on the age-at-death distribution than mortality has (McFadden & Oxenham, 2018). This could be an effect of mortality being difficult to investigate, but could also mean that the key to study paleodemography can be found in the fertility of a population. One major impact on fertility is the age of the reproducer, a young reproducer has positive effects on fertility while an old reproducer has negative effects on fertility when it comes to population structure in general (Hawkes, 2008:18). The most important factors in fertility are the biological mechanisms such as breastfeeding intensity, diet, seasonal variance in diet, and female activity (Kelly, 2013:212).

4. Material

The 1950's excavations of S: t Nicolai cemetery resulted in the exhumation of 375 individuals, 27 belonging to children. Due to temporal restrictions only parts of the material was examined in this study, resulting in a selection of 75 individuals that were chosen for osteological investigation. The selection was based on the documented placement of arms in the graves, providing indications of when the individuals were buried. The intent of this selection was to restrict the time span in order to produce reasonable paleodemographic data, instead of spreading the data over centuries. The arm positioning of Medieval skeletons also coincides roughly with shifts in Medieval health where the positions A and B were used during the Early and High Middle Ages whereas positions C and D can be derived to the Medieval decline in Europe. More on medieval skeletal dating follows below. However, one of the graves was excluded because of it being a child belonging to a double grave in which an adult individual was buried with arm position D making the grave much younger and not fitting the frames of this study.

4.1 Dating skeletons

By observing the positioning of the arms of buried individuals from medieval cemetaries, Redin (1976:33) was able to establish a chronology and typology of these positionings and in addition produce approximate dating in correlation. He could distinguish four main positionings which was designated the letters from A to D where A represented the oldest positioning. The position for A is the skeleton in a supine position with the arms lying along the sides of the skeleton. The subsequent positions all are in supine positions but with the arms crossed progressively higher up on the torso of the individual. The B position displayes crossed arms over the pelvic area, the C position with crossed arms over the stomach and the D position with the arms crossed over the chest (Redin, 1976:32-33). Later research has refined the method of arm positioning but in all, it is regarded as relevant and reliable (Lovén, 2011:348-349). The correlation between the positioning and dating are as follows: Type A: 900-1250 CE, type B: 1250-1350 CE, type C: 1350-1400 CE, and type D: 1400-1500 CE. Illustrations of the positionings are presented in Fig 2.

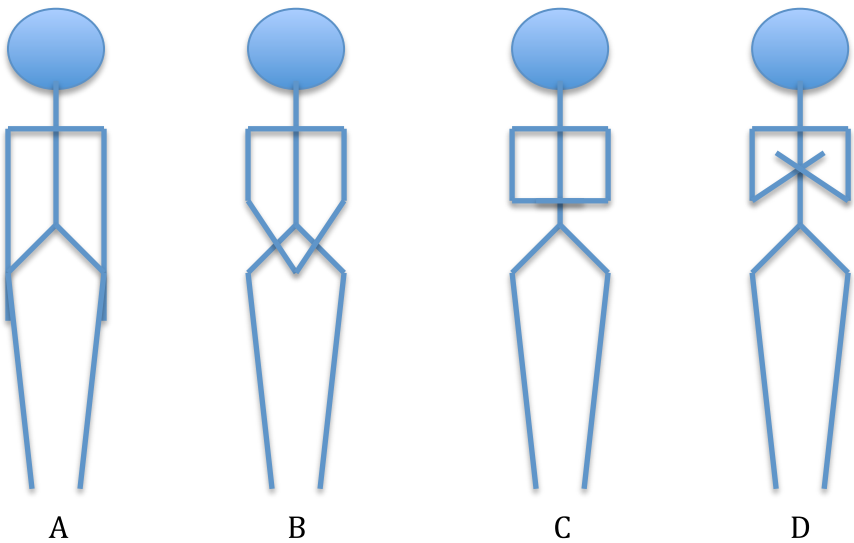

Fig 2. Arm positionings according to Redin (1976:32-33).

Since the Medieval decline starts in Europe shortly before the Black Death hits the continent in 1347, there is consenses that populations living before the decline and after were heavily diverse. The focus for this study is therefore on the population buried before the catastrophic event of the plague corresponding to arm positionings A and B. The reason for the selection of pre-plague population is that it is believed to represent a more representative part of a Scandinavian Medieval society rather than one affected by an epidemic event. During the outbreak of the Black Death, Helsingborg belonged to Denmark and even though the population of that time is unknown, the Kingdom of Denmark is believed to have been a strong, powerful and densely populated area. The city of Helsingborg was established along the coast with the purpose of providing interconnectivity and trading opportunities and it is especially these kinds of places that have shown to be heavily affected by the plague. The Black Death is believed to have raged the Danish Kingdom starting in 1349 (Benedictow, 2004:159).

In order to proparly investigate the effects of the plague, you have to know how the populations affected was before the epidemic hit and also calculate how that very population would be if the epidemic never hit. You need to find a ”control cemetery” and compare the two to each other. No such cemetery exists. In cases where necessary data is unavaliable, models can be used (DeWitte, 2006:34-35). In cases where data do exist, models should not be used, but the data should stand by itself. Therefore, inhumations that might have been results from the Black Death have been excluded.

The number of individuals buried according to type A positioning is four, representing 1 % of the total number of exhumed individuals and the number of individuals according to type B positioning is 71, representing 19 % of the total number of buried individuals exhumed (Hök & Kindström, 2005:37). In total, 75 individuals were analysed. Apart from arm positioning, there were no reliable approaches for dating the burials. Among the collected grave goods, a variety of objects with datable features were present, however these objects have lost connectivity with contexts through time and unfortunatly could not be used for dating purposes. There have neither been any scientific analyses made, such as dendrochronologic or isotopic sampling, leaving the material instead dated by historical documentation and arm positioning. The S: t Nicolai convent was established in 1275 CE, meaning that the four individuals buried according to arm position A should have been buried before the convent was established. This might have been correct and can be confirmed by investigating the drawings from the excavation in which some of the skeletons are recovered from underneath the original chancel walls. The individuals in question are either poorly preserved and have elements missing whereas arm positioning cannot be determined. All individuals identified as being buried according to arm position A were recovered from different parts of the North cemetery. These factors indicate that the area was used as a Christian burial site before the Dominican convent was established. This further means that the studied individuals buried according to arm positioning B all died within a span of 75 years, corresponding to some of the individuals' lifetimes, making the cohort well suited for the application of life course theory.

5. Method

The studied material was examined at Kulturmagasinet in Helsingborg. The individual boxes with the exhumed skeletons are stored in the temperate basement of the depository and were examined in the same location. The repeated relocating of the material and documentation from the S: t Nicolai excavation has made the management of it difficult. Contexts have been lost as well as linkage between finds. Some of the bones in the graves have been mixed making assessments of age and biological sex challenging. In some cases, more bone elements than what should be present are present in the boxes. This includes multiple mandibles or vertebres. In other cases, the skeletal elements does not match each other in that sense that a mandible with remaining teeth indicate one age while the rest of the post-skeletal elements suggests another. In all cases, the deviating elements have been excluded and disregarded for the analytical purposes of the study.

In this study, a qualitative analysis is conducted from quantitative data. The quantitative method is most suitable for statistical analysis and when processing a large number of measurable observations. The quantitative method is deductive and will thus provide logical conclusions based on one or more statements and are the preferred method for testing hypotheses (Hoy, 2010). The qualitative analysis uses the collected data to extract representation and meaning in order to apply social context to statistics. In social studies, quantitative research often reduces people into numbers whereas qualitative research reduces them into words (Bernard, 2018:355). Both approaches are necessary for this study for the purpose of bringing meaning to scientific data extraction.

5.1 Machine learning

Transition Analysis 3 uses machine learning theory in order to calculate the ages of individuals. The method automizes model building in analytical research. Machine learning is an Artificial Intelligence based system that mimics human intelligence by learning to detect patterns in the data that is being analysed. This pattern recognition uses deep learning networks that are contructed much like the human brain with neurons connecting processes to each other uses multiple algorithms in order to imitate how the primary visual cortex handles information (Vieira et al., 2019:3). Machine learning is constructed for supervised learning, unsupervised learning or reinforcement learning. Supervised learning can be based on classification or on regression whereas unsupervised learning is based on clustering or dimensionality reduction (Schmidhuber, 2015:88-89). Unsupervised learning is suitible for Big Data visualisation, structure discovery or targetted marketing. Reinforcement learning is a closed-loop system that uses computional rewards when tasks are performed and solved successfully (Sutton & Barto, 2018:2). Reinforcement learning is often used for robot navigation, real-time decisions or game AI. The machine learning system used for TA3 is based on supervised learning and uses regression theory. Regression analysis describes the relationship between dependent and independent variables. The dependent variable must be continuous but the independent variables can be continous, binary or categorical (Schneider et al., 2010:776-777). Since age is a continuous variable, it is used in Transition Analys.

5.2 Assessing sex

Juvenile individuals were not assessed by sex. Assessment of sex on adult individuals was based on indicating traits found on the pelvis and crania for adults. The methods used were the primary and secondary standard assessment methods based on cranial and pelvic traits. The secondary traits are all found on the crania (Acsádi & Nemeskéri, 1970) and were scored according to Buikstra & Ubelaker (1994). The primary traits are observed on different parts of the pelvis (Mehmet et al., 1962; Phenice, 1969; Milner 1992). The assessment was primary based on pelvis characteristics, however, when the pelvic traits were unidentifiable, secondary traits were observed and combined in order to assess biological sex. If the traits displayed contradiction or ambiguity, biological sex was determined as ambiguous, if none of the pelvic traits were avaliable for observation and the assessment was solely based on secondary traits, the assessment was categorized as either *F?* or *M?*. The *F?* was nevertheless included in the *F* category (As well as *M?* in the *M* category) when the entity of the material was analysed.

5.3 Assessing age

5.3.1 In juveniles

Juvenile individuals were aged by assessing dental eruption and osteochondrosis of bones and epiphyses according to avaliable methodology developed by Scheuer, Black & Schaefer (2009) regarding measurements of *pars basilaris*, fusions of *vertebrae* and fusions of the *pelvis*, Black & Scheuer (1996) for measurements of the *clavicula*. Maresh (1970) was used for measurements of the *humerus, radius, ulna, femur, tibia* and *fibula*, Molleson & Cox (1993) for measurements of the *ilium*, Cardoso (2008) for fusions of the *pelvis*, Garn, Rohmann & Silverman (1967) for epiphyseal fusions of *ossa pedis*, Birkner (1978) for osseus development of *ossa pedis* and Ubelaker (1979) for dental eruption and development.

5.3.2 In adults

5.3.2.1 Transition Analysis 3

The data was collected through osteological examination and observation and trait scoring manuals was filled in for each of the individuals. In each of the individual skeletons, 62 possible traits could be identified. The traits are placed on various areas of the skeleton and do not require the presence of complete skeletons or certain parts of it in order for the analysis to be conducted. The data was then inserted in the ADBOU, which provided with assessed ages of the individuals. The traits in question are presented in Table 2.

Table 1. Distribution of TA3 traits by element. Traits that will be removed from future analyses in red.

Cranium	*Vertebrae*	*Sternum & Ribs*	*Upper limb*	*Lower limb*	*Auricular surface*	*Pubic symphysis*
-Parietal depression	-C1 lipping -C1 eburnation	-R1 fusion	-Clavicle medial epiphysis fusion -Clavicle medial epiphysis gravel -Clavicle medial macroporosity -Clavicle lateral	-Femur fovea margin lipping -Femur head surface extra bone -Femur greater trochanter roughening -Femur trochanteric fossa exostoses	-Inferior surface porosity -Superior posterior iliac exostoses -Inferior posterior iliac exostoses -Posterior exostoses	-Pubic symphyseal collar -Symphyseal relief -Superior protuberance -Ventral symphyseal margin -Dorsal symphyseal

			macroporosity	-Femur trochanteric medial exostoses		margin
-Spheno-occipital synchondrosis	-L1 Spinous process flattening -L1 epiphyseal ring fusion -L1 surface morphology	-Sternum central dorsal ridge	-Humerus weight -Humerus lesser tubercle bumps -Humerus lesser tubercle margin shape -Humerus greater tubercle pits -Humerus medial epicondyle -Humerus lateral epicondyle	-Tibia weight		
-Occipital condyle lipping	-L5 epiphyseal ring fusion -L5 surface morphology -L5 margin shape	-R2 & R3-10 sternal end rim profiles -R2 & R3-10 shingle ribs -Rib ossification pattern	-Radius tuberosity medial crest	-Fibula wings		
	-S1 margin shape -Sacral elbow		-Ulna olecranon spur	-Calcaneus weight		
	-Vertebral lipping -Vertebral candlewax -Vertebral DISH		-Trapezium lipping	-Innominate weight		
				-Sacroiliac joint fusion		
				-Iliac crest fusion -Iliac crest tuberculum ossification -Ilium AIIS exostoses		

				-Acetabulum posterior margin lipping -Acetabulum articular surface extra bone -Acetabulum inferior joint lipping		
				-Ischial tuberosity superior margin spur -Ischial tuberosity medial spur -Ischial tuberosity bumps		

The developers of TA3 have referred from the appliance for some of the skeletal traits. Certain traits are included for educational reasons while others have been proven unnecessary and will for later versions be removed. The traits in question are DISH (Diffuse Idiopathic Skeletal Hyperostosis) wich has proven to be indicative of selective mortality, and fibula wings, ischial spur, R1 fusion, radius tuberosity crest, ulna olecranon spur and sacral elbow which add little or no useful information for age assessment. Some of the traits such as closed spheno-occipital synchondrosis or fully fused vertebral rings have been disclosed by the developers as unnecessary traits for analysis, but will in return help narrowing down age ranges and thereby limit the results (User Guide TA3, 2020). When present, all traits were however registered and used for this study, something that could have had the effect of lowering the ages of some older individuals.

6. Analysis & Results

In total, 75 individuals were analysed. In eight (11 %) cases, the skeletons belonged to children. Biological sex was able to be determined for every adult individual except for one. From all adult graves that are considered High Medieval, 13 (17 %) belonged to women, 53 (71 %) to men and for one (1 %) adult individual, age was assessed, however, biological sex could not be determined (Fig 3).

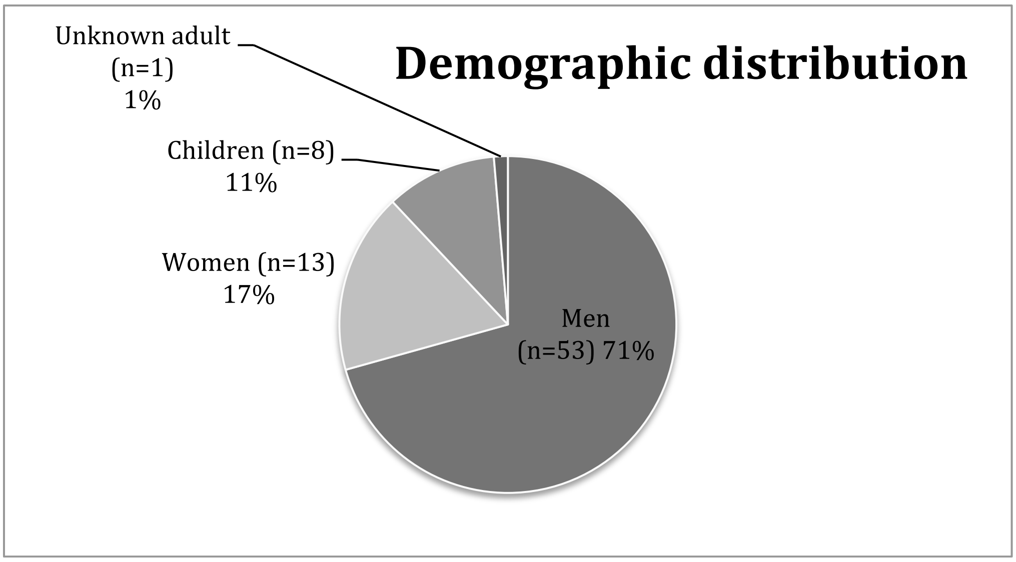

Fig 3. High Medival populatory distribution at S: t Nicolai cemetery.

6.1 The children

Out of the total population from the High Medival parts of S: t Nicolai's cemetery, eight were children. These eight children represented 11 % of the entire studied population. Their ages were assessed according to traditional juvenile age estimation methods, however, in some cases, ages were based on measurements of bones that fell in between specific age measurements. In these cases, the final assigned age were therefore also placed in between, making the children (*X*), 5 years old (Table 3).

Table 2. Age distribution of children from High Medieval graves at S: t Nicolai cemetery.

The children of S:t Nicolai								
Grave	**46**	**64**	**138**	**142**	**187**	**231**	**300**	**504**
Age	13.5 years	9.5 years	7.5 years	7 years	11.5 years	13.5 years	12.5 years	11 years

When determining the final resting place for the eight buried children, it became clear that their graves were distributed all over the convent. Three of the children were buried within the long house, one of which inside a brick casket. The remaining five children were buried in the cemetery without any apparent coherence. Mainly dental eruption and bone lengths could age most of the children, and those results also matched each other. However, for one of the graves, no. 142, they did not. Dental eruption suggested that the individual was seven years old when they died, whereas the length of the remaining bones suggested an age of two to three years. There were no indications that the grave had been mixed or contained multiple elements. The grave in question was also situated by itself in the cemetery. The results of the age assessment were interpreted as an effect of the osteological paradox as well as a typical example of life course theory. After all, something caused the death of this child and if the child had been ill for an extensive period, perhaps the entirety of its existence, that would have impacted the health on the individual as well as had en effect on bone development. Dental eruption, however, is not affected in the same way by temporary health decline. The results from estimating age for this young individual reveals that the general health was good enough for children to survive long term illness, however that long term illness caused by stressors such as mortality risk, cardiovascular disease or chronic infection had great developmental inhibitory effects (Temple, 2018). The health was good enough for survival, but never good enough for overcoming the stressors.

6.2 The adults

The High Medieval adult population at S: t Nicolai cemetery amounted to 67 individuals. These 67 individuals represented 89 % of the total studied population. The youngest adult individual was estimated to have been 26.6 years when death occured. The oldest individual was estimated to have been 82.2 years old. The median age for adults was 55.15 years and the mean age 53.7 years-at-death. The mean age-at-death for the total population was 49.3 years. The children reached an average age of 10.75 years, those assessed as men reached 54.6 years of age and women were 50.3 years on average when they passed away. The one individual whose sex was unable to determine was 55.1 years old when death occured and is presented separately in the Table 4.

Table 3. High Medieval age-at-death at S: t Nicolai cemetery

Mean age-at-death at S: t Nicolai cemetery	
Men	54.6 years
Women	50.3 years
Unknown adult	55.1 years
Children	10.75 years
Total	**49.3 years**

Some of the graves could not be located on the drawings that were attached to the 2005 report of the 1950's excavation. These graves were no. 127, 150, 236, 299, 301 and 405. Graves 236 and 299 belonged to women. The remaining eleven female graves from the High Medieval period were distributed along the chancel, longhouse and the North cemetery. The only area without any High Medieval female graves was the northeastern longhouse chapel. It was noted in the excavation report that all the 16 individuals recovered from the northeastern longhouse chapel had the same prominent jaw, making the assumption that they were all related to each other. The report also states that the Northern cemetery was the final resting places for the Dominican friars, however, eight of the High Medieval female graves were recovered from that area.

Three of the graves were lined with lime, no. 23, 150 and 315. Grave no. 150 could not be found on the drawings. Grave no. 23 was found in the middle of the chancel and no. 315 in the middle of the Northern cemetery. The tradition of lying charcoal or lime in graves appears to have been a mainly Early Medieval custom. To lay the dead on top of a charcoal bed was a practice that seems to have ended during the 12th century, however limed graves can be found up to a century later. The charcoal and lime was probably used both as symbols of ash and cleansing, but also consolidated the holyness of the place. In other uses, the charcoal and lime might have worked as absorbers of smells and liquids as well as an accelerant for decomposition (Cinthio, 2002:44-52; Jonsson, 2009:122-123).

When the ages are calculated in the TA3 ABDOU software, a specific age is presented as a point with an accompaning age range from which that point is derived. The ranges differ between individuals depending on the number of, and score of, identifiable traits in the different individuals. In other words, consistent age indicating traits, as well as better preservation of skeletons provided narrower age estimation ranges. Age ranges are used in all age estimation methods because of morphological variation in humans. In

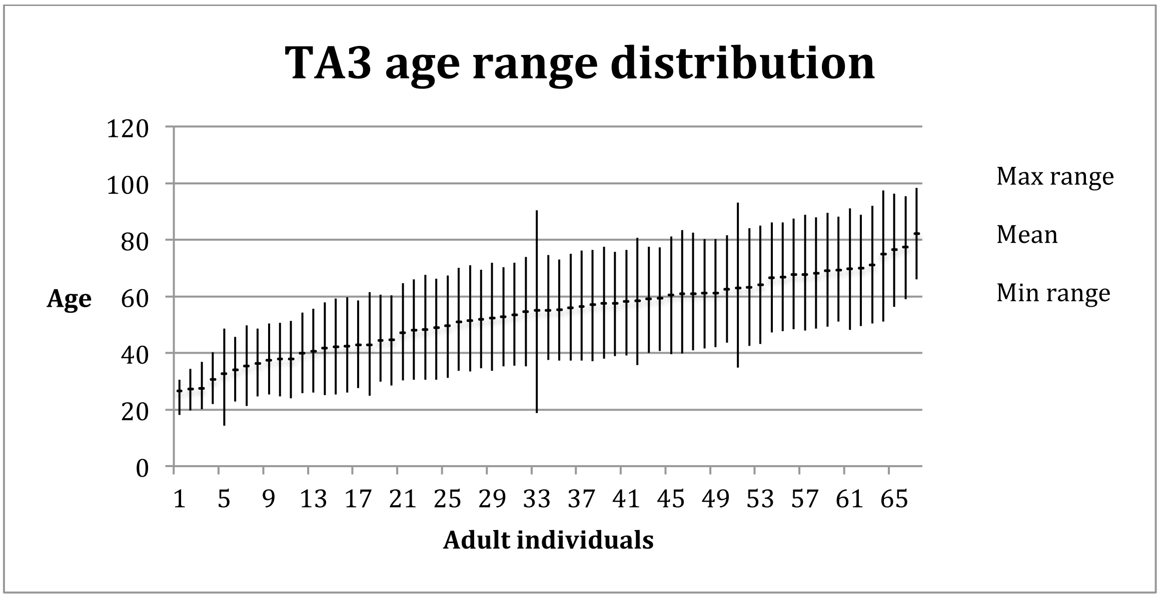

Fig 4. Distribution of calculated TA3 ages and ranges.

traditional age estimation methodology, one of the big issues is the uncertainty in assessing age in older adults as well as increasing age ranges with older age groups. The age ranges from S: t Nicolai cemetery were documented in order to find out if the TA3 also produced increasing and more uncertain age ranges with older ages (Fig 4).

The results show that the age ranges are narrower towards the younger ages (<55 years), however, for the ages between 55 years and up, the age ranges are rather consistent, apart from a couple of individuals where the result eventuated in large spans due to poor preservation and thus few indicative traits. The two individuals (201 & 261) were both extremely fragmented. Individual 201 only displayed seven out of the 62 traits and individual 261 only displayed five. Biological sex was assessed as unknown for individual 201 and as *M?* for individual 261. Even though the age span is large, some of the traits are more indicative of age than others and the method is still able to pin point a most probable age. This same phenomenon in previous studies could be one of the reasons behind ageing individuals as *20+* years old. It is possible to determine that the individual is adult, however the methods used leaves no other option than assessing no more than just that that. The difference in average age range between men and women at S: t Nicolai cemetery was 3.3 years. The age span for women was 33.2-67.5 years and for men 36.8-74.4 years (Fig 5).

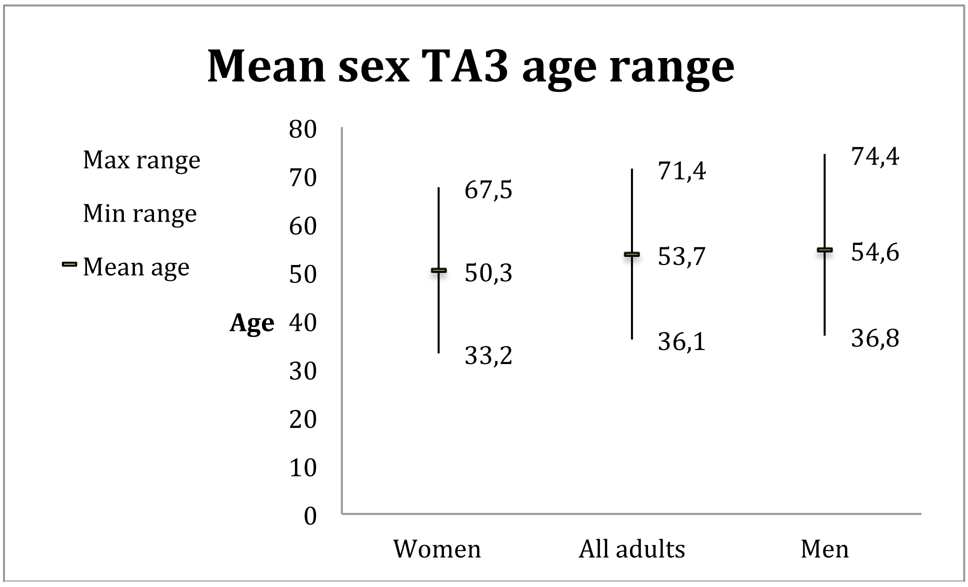

Fig 5. Average age and range of calculated TA3 for women, men and all adults.

The difference might be an effect of the inclusion of individual 201 which was poorly preserved and whose age could only be assessed using a total of seven TA3 traits. It could also be an effect of the sensibility of the method for the different sexes and needs to be studied further. The developers of the TA3 method are planning on developing separate assessments for the two biological sexes, comparisons between this study and future ones will therefore be interesting to follow (User Guide TA3, 2020:4).

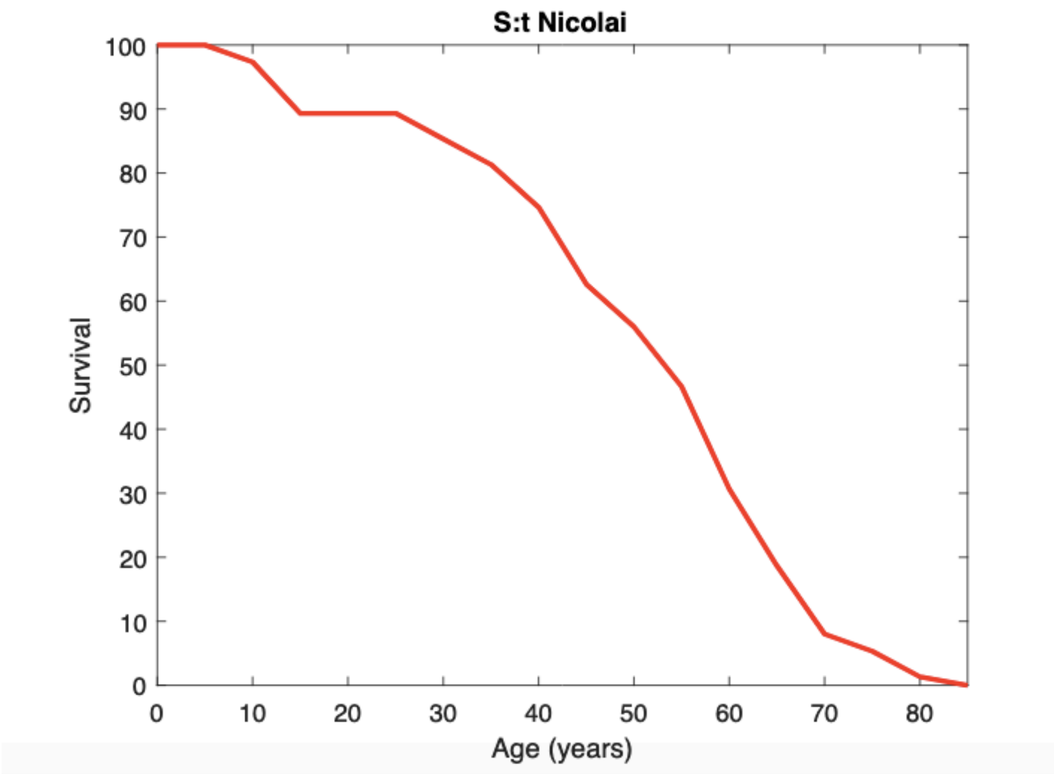

Fig 6. Survival rate for the High Medieval population from S: t Nicolai cemetery.

The survival rate of the studied population is illustrated in Fig 6. The figure displays survival of 100 individuals in the given population from birth to death based on the data provided by the TA3 analysis. The expected remaining years for survival from birth, or the life expectancy on average, is 49.3 years. At the age of 85 years, no High Medieval individual from S: t Nicolai cemetery has survived. The small amount of children presented in the material provides a much slower decrease in survival rate compared to similar populations (for further population survival rate comparisons, see Burger et al. 2012).

For the age assessment method based on the pubic symphysis by Brooks & Suchey (1990), the standard deviation was calculated to being 18 by the authors themselves. However, in the validation study by Sarajlić & Gradaščević (2012), their investigation of individuals killed in the Bosnian & Herzegovian war showed that both the standard deviations as well as the statistical significance were incapable of reproduction. The standard deviation was calculated to 22, however the mean age span for individuals younger than 35 years was around a decade, and for individuals 65 years and older, it was three. The p-values for the Pearsons hi square test were only significant in two out of six age group comparisons. Not only Sarajlić & Gradaščević (2012) has reported inconsistencies with the Suchey-Brooks method, but also Savall, Rérolle, Hérin, Dédouit, Rougé, Telmon & Saint-Martin (2016). Their study on contemporary French men showed that the results provided by Brooks & Suchey (1990) could not be replicated and instead, the method displayed larger bias than previously reported. The method also had increasing spans with increasing age resulting in almost twice as large spans for compared groups of different ages. The values for the standard deviations resembled those of Sarajlić & Gradaščević (2012) and the authors also found the method to be biased against multiculturality and made their inital material selection based on male individuals only, since it has previously been reported as being biased against female specimens (Savall et al., 2016). When the results from this study is compared to the age ranges and standard deviations to two of the most used age assessment methods by Brooks & Suchey (1990) which is based on Todd (1921a, 1921b) and by Todd & Lyon (1924). The cranial suture fusion method displays high age ranges throughout life since it does not include sex or ethnic variation. Comparisons between the Brooks & Suchey (1990) method and TA3 are therefore more interesting. In the younger ages, age ranges for the pubic symphysis and TA3 are similarly low. For the older ages, ranges increase for both methods with increasing age. The Suchey-Brooks method has the changes in the pubic symphysis divided into six phases. Each phase is illustrated with imagery as well as written criteria, which differ, for the two biological sexes. When the results from the TA3 analyses from this study are divided into corresponding age phases, it is possible to compare the age ranges as well as the standard deviations. Since the Suchey-Brooks method differs between biological sexes and that women are underrepresented in this study, only the male cohorts are compared (Table 4).

Table 4. Age ranges and Standard Deviations for Brooks & Suchey (1990) and High Medieval S: t Nicolai cemetery. The * marks the SD for Phase VII if individual 261 were to be included.

	Suchey-Brooks (1990)		*S: t Nicolai*	
Phase (age)	**Range**	**SD**	**Range**	**SD**
I (18,5)	15-23	2.1	*n.a*	*n.a*
II (23,4)	19-34	3.6	*n.a*	*n.a*
III (28,7)	21-46	6.5	20-35	5.8
IV (35,2)	23-57	9.4	25-53	11.3
V (45,6)	27-66	10.4	31-66	7.2
VI (61,2)	34-86	12.2	38-77	8.4
VII (67,4)	*n.a*	*n.a*	47-88	5.8 (*21.3)
VIII (79,4)	*n.a*	*n.a*	61-97	7.7

When the age range and standard deviation results are compared between the two ageing methods, the one thing that clearly differs is the age distribution. TA3 is able to detect older ages than the Suchey-Brooks method. For the Suchey-Brooks method, the standard deviations are increasing with increasing age phases, however with TA3, the standard deviations are more inconsistent, which probably depends on assessments made on more taphonomically challenged skeletons. The S: t Nicolai cemetery did not contain any individuals corresponding to *Phase I* or *II*; therefore, these results cannot be compared. The Suchey-Brooks method is only applicable on individuals up until *Phase VI*, the additional phases were created for the purpose of visualizing the extent of the TA3 method on the S: t Nicolai material. The standard deviation for *Phase VII* includes individual 261, which was one of the individuals that was poorly preserved and was only assessed by a total of five TA3 traits. The possibility of including these fragmented individuals in paleodemographic results can be both valuble as well as scientifically challenging. By being able to include more individuals, the perspective broadens; however, the validity of the method reduces since deviations can differ greatly. An option would be to make a selection based on the turnout of the age range provided, ultimately discarding ranges over a certain span, although, that might prove to have the same effect on the total population as placing individuals in a *20+* category.

When comparing the results from this study to similar ones with disclosing data from populations in current London, Lund and Medieval Denmark, several differences can be identified (Table 6). S: t Nicolai displays a much older general population than any of the other. S: t Nicolai is deviant in the sense that it does not present any infants or young children, as apart from all other locations. The life expectancy is also higher at S: t Nicolai cemetery, much higher than the populations presented by Arcini (1999), but also higher than presented by DeWitte (2015) which is interesting due to the fact that DeWitte used the TA2 age estimation method. Differences can also be seen in overall age distribution between the populations. For the London population, the majority of deaths occured between ages 10-34.9 years. For the Lund population, child mortality was high but mortality was also high for individuals between 20-39 years of age. For the overall Medieval Danish population, most deaths occured within the first 14 years of life, but high mortality is also seen between 20-59 years of age. For the S: t Nicolai population, the majority of deaths occured between ages 40-59 years of age, however a big part of the population lived past 55 years of age and many even past 65 years. By identifying the really old individuals, the population at S: t Nicolai cemetery follows more natural mortality patterns than the other compared material. By using the TA3 method, assessing individuals as *20+* years old could be avoided and the individuals could be included in the main cohort.

Table 5. Age group comparisons of Early and High Medieval London populations (DeWitte, 2015), and Medieval Lund and Denmark populations (Arcini, 1999) to S: t Nicolai High Medieval population. Data from DeWitte (2015) are extracted from published Fig. 1 in article.

Age Group	London % (DeWitte, 2015)	S: t Nicolai %
0-4,9 years	5.6	0
5-9,9 years	5.7	4
10-14,9 years	25.5	6.7
15-24,9 years	14	0
25-34,9 years	13	8
35-44,9 years	4	20
45-54,99 years	2.5	14.7
55-64,9 years	2.5	28
65-74,9 years	13.5	13.3
75-84,9 years	*n.a*	5.3

Age Group	Lund % (Arcini, 1999)	Denmark % (Arcini, 1999)	S: t Nicolai %
0 years	4.8	15.5	0
1-6 years	10.8	15.1	0
7-14 years	9.7	10.1	10.7
15-19 years	6.1	7.2	0
20-39 years	30.4	19.1	14.7
40-59 years	12.8	18.7	44
60-70 years	3.3	5.6	22.7
70-80 years	*n.a*	*n.a*	6.7
80-90 years	*n.a*	*n.a*	1.3
20+ years	22	7.5	*n.a*

The total fertility rate (TFR) is often calculated in paleodemographic analyses in order to detect growth in a population. It is also a key factor in producing life tables. The TFR is the calculation of how many children the average woman will give birth to during her lifetime and is based on her number of reproductive years. In populations where women are likely to reach older ages, the amount of reproductive years increases, as apart from in populations where women are prone to die young (McFadden & Oxenham, 2017.). However, for the study at hand, TFR was not calculated because of the apparent bias at the cemetery towards a naturally growing population. The number of women was few and since the cemetery was primarily dedicated for the friars of the convent, the connectivity between the women and the convent is unknown. To calculate TFR for the High Medieval population of S: t Nicolai cemetery would in the author's opinion not add any valuble data, but would rather lead to direct misinterpretations of the bigger population. However, the individuals from the entire cemetery would be analysed, the argument of including the TFR in that context might prove more informative.

7. Discussion

To reconnect to the main objective of this study, Transition Analys 3 is a useful tool for estimating age in High Medieval populations. The method works best when assessing material that are somewhat complete and is represented by several elements. If the material would have been mixed or only represented by single elements, TA3 would not be useful in it's full potential. The paleodemographic analysis of S: t Nicolai cemetery displays a surplus in male graves. It also contains eight children that died between the ages of 7-13.5 years. Even thought the cemetery, or certain parts of it, was dedicated to the friars of the convent, several women were buried in the same. The average life expectancy at birth was 49.3 years and men lived in general for almost five more years than women did.

When comparing results from the study of S: t Nicolai cemetery to those made by Arcini (1999) and DeWitte (2015), the difference in age distribution, as mentioned earlier, is the most prominent factor. The age distribution of S: t Nicolai displays an older population in general, where the majority of individuals belong to the older age groups. The study by DeWitte (2015) instead mirrors a significantly high mortality in children and younger ages whereas the study by Arcini (1999) projects high mortality in middle aged individuals. High mortality in younger ages is connected to infectious disease and crowded settled areas, corresponding with outlines of the study by DeWitte (2015) (Gurver & Kaplan, 2007). Mortality in older ages is linked to degenerative illnesses, which would be the case for the S: t Nicolai population, whereas mortality in middle aged individuals is connected to interpersonal violence and accidents. Mortality is affected by a variety of variables, epidemics being one of them. Since the study of Arcini (1999) includes individuals from the entire medieval period, the results might therefore reflect a population deeply affected by the Black Death. However, it is also possible that they reflect insufficient age estimation methodology.

There are apparent differences when comparing the paleodemography of S: t Nicolai cemetery to other populations. When comparing the results of this study to previous ones made on Medieval Denmark, Early and High Medieval London and medieval populations in current Moldova, average age and distribution of age is significantly higher in the S: t Nicolai population. Whether this is a methodological effect or a reflection of society at that time is difficult to determine in the compared material, however, comparisons of standard deviations between TA3 and the most commonly used age assessment methods proves TA3 to succefully detecting older ages without comprimising the accuracy of the assessment. To use the method, only two traits of the lot needs to be present in order to pin point an age estimate. This makes the potential far greater than for any traditional method as this avoids estimations that only distinguish juveniles from adults or estimating individuals as simply *20+* years old. The High Medieval period was compared to the later medieval decline a prosperous and expanding environment. Such an environment is unlikely to provide circumstances for which middle age individuals would die to such an extent as the compared material indicates. The results from this study generate much more likely mortality profiles where the population followed more natural models of death. Even though child mortality probably is not representative in the S: t Nicolai population, the representation of old age is significant. The oldest individuals reached ages of around and over 80 years of age and had lived their whole lives during the High Medieval period, corresponding to Redin's arm position B (1976). The results show that these people had full potential for reaching older ages and probably died from degenerative and natural illnesses rather than from violent interpersonal encounters or hazardous lifestyles between ages 20-40 years of age.

The hypothesis for this study was that the application of TA3 would provide paleodemographic disparities due to methodological issues with traditional age estimation. The results from the TA3 age assessments were also believed to contribute to the life history of single individuals. The results have shown significantly older ages-at-death compared to traditional age assessment methods. By detecting these older ages in populations where they previously have not been expected to be present, it is not only the paleodemographic processess of mortality, fertility and mobility that are affected, additionally, the life course of the individual gains great information in terms of health, living conditions and environment. The results have shown an extreme increase in age for older adults compared to previous research, baring in mind that some of the registered traits are being removed for future releases of the TA3 method, age estimates are expected to increase even more so. The results from this study also reflects natural mortality patterns and resembles modern life courses and expectancies much more than previous research has indicated. This reconnects to the idea of humans being able to reach really high ages given favourable environmental preconditions (Burger et al., 2012). The survival rate of the studied population display a very different curvature compared to similar populations, with a high survival rate early in life and an elongated decline in survival throughout older adult ages. Methodology alone is unlikely to produce such curvatures; low representation in children probably is the reason for the high survival rate in early life, and methodology for the slow decline.

The final resting place for the friars of the S: t Nicolai convent is rapported to have been north of the chancel. Although, according to the results in this study, that part of the cemetery was also the resting place for both women and children. Whether these women and children were affiliated with the friars is unknown, however, the convent is said to have taken in orphaned and abandoned children where they were looked after and educated. In that sense, the convent was at that time the biggest organized charity (Hök & Kindberg, 2005:17). This might explain why there are children buried among the friars. From the area north of the chancel, a total of 311 individuals were exhumed according to the documentation (Hök & Kindberg, 2005:18). However, it also states that additionally, 126 individuals were exhumed from the other parts of the convent and these add up to alot more people than the 375 individuals that was identified when report was written in 2005 and also that present in the basement of Kulturmagasinet. This tells us that either the documentation is inaccurate or that individuals have been lost since the excavation. Many of the graves investigated for the purpose of this study were mixed and contained elements belonging to other individuals within their boxes, this might also explain why there are fewer reported graves between 1954 and 2005, since some graves might have contained few elements in total and then was possibly mixed with remains from other graves. Estimations by Kindberg (Hök & Kindberg, 2005:17) surmise that the amount of friars in the convent should have been around 20 people, based on the tradition of having at least twelve friars at every convent, and also based on the size and activities at S: t Nicolai. Now, if the children and staff were to be included in people that might deserve privilege to be buried among the friars, we can guess that it might sum up to twice as many as a maximum. Since the convent was active for just under 300 years and the mean age was roughly 49 years (althought a lower mean age-at-death is assumed for the later parts of the Middle Ages), a quick aggregation suggests that about 215 of the buried individuals should have been affiliated to the convent and hence entitled of being buried among the friars. This however leaves almost 100 individuals north of the chancel, not to mention the remaining 70-126 people (depending on original documentation or actual present individuals). The question is if these additional individuals were affiliated to the convent or if they, as Arcini (2020:105) mentioned, bought their burial place at the cemetery. This might also be an important contributing factor to the overall high distribution of the cemetery since many of the buried individuals might have been privileged and by extension have better prerequisites for increased health than populations buried in other Helsingborg cemeteries. The entity of the population buried at S: t Nicolai cemetery along with contemporary populations in adjacent Helsingborg cemeteries should therefore be included in future research to get a fuller understanding of the life courses of High Medieval Helsingborgers.

The age assessment method based on the synostosis of cranial sutures is and has been widely used in both osteological examinations, as well as in forensic. The method was first developed by Todd & Lyon (1924), but has since been revised by Masset (1989) and modified by Buikstra & Ubelaker (1994). Hershkovitz et al. (1997), investigated the statistical significance for the method and found that the Spearman rank correlation coefficients only found correlations in some of the suture closures and only when widening the age span to 20-49 years of age. No correlation was found with suture closure and ages 50-99 years. The ageing method of suture closure has also proven time and again to be majorly affected by age mimicry and is chronically biased against biological sex and global populations. In order to improve the p-value of the results in the study by Hershkovitz et al., (1997), the age groups needed to be adjusted from the original 5-year intervals into only two major groups: 25–44; 45–70 years. Even after the age groups were adjusted, many of the traits that the method is based upon, was discarded and regarded as highly irrelevant and incorrect (Hershkovitz et al., 1997). This method is still widely used in bioarchaeological research, however displays multiple insignificant results, and should therefore be replaced by the TA3 method which also uses cranial features for its estimation, however, other traits than the sutures are used.

What the results clearly demonstrate is that the S: t Nicolai convent was anything shy of a conventional parish church. In similar contexts, cemetaries are rich in graves for infants and young children. The norm would be to bury small children southeast and south of the chancel, close to the church roof so that the rain would turn into holy water as reaching the church building and late falling onto the graves (Jonsson, 2009:62). This area at S: t Nicolai cemetery was instead dedicated to conventory adjacent buildings and suggests that there was never any intention of burying small children at the cemetery. The area north of the chancel contained men, women and children of older ages, even though that area was intended for the friars of the Dominican Order. Several studies of Medieval cemetaries display a slightly elevated ratio in buried men (Iregren, 1988:39; Arcini, 1999:55, 61; Simalcsik et al., 2013), however, not at all in the manner as S: t Nicolai cemetery, which would have led to extinction, would it reflect actual society. The question should maybe not be why the composition of the cemetery differs from conventional ones, but rather, what made the individuals present so special that they circumvented the standards of Dominican burial rituals.

Buikstra & Konigsberg (1985) argues that the most important thing that needs to be mapped is differential reproduction and the survival of the human kind, in so many words, the human evolution. That might seem as an all too big task to take on and that might also be the source to the criticism that the field has endured. Buikstra & Konigsberg (1985) further states that the evolutionary development can be detected by using paleodemography as long as the researcher is well acquainted with the methods used and as long as the research is conducted in a systematic manner. Bouquet-Appel & Masset (1982) stresses the important potential found in paleodemography but as frontrunners in the critical mass bade farewell to the field in the early 1980's due to what they considered as being a science filled with "*random fluctuations and errors of method*" (Bocquet- Appel and Masset 1982:329). In the 1980's, paleodemography was an uncoordinated mess with researchers from archaeology, anthropology, forensic anthropology and demography all conducting their research in their own way without collaboration or communication (Buikstra & Konigsberg, 1985). Since then, reseachers have realized that the task of mapping human evolution is better handled with help and expertise of people with different backgrounds and knowledge. Paleodemography has the possibility to from a wider perspective investigate social dynamics and identify population-wide patterns. The criticism directed towards the field has paved the way for better methodology and collaboration between scientists working within paleodemography. Archaeology and biogeochemical alone can only contribute to tracing individual actions and movements in a landscape but by adding demographical data and statistics, the field becomes more holistic and the results more reliable. Paleodemography is a useful tool for understanding processes like migration, colonization and repatriation and can be significant for populations today. By improving the methodology it is possible to make new assumptions about the health of past populations and also discard old assumptions based on old and inaccurate methodology. Recent studies in current Peru indicate that children in the studies population had much better survival rates than previous studies have shown. This also indicates that both health and fertility probably was higher for that population and those previous assumptions about Mesolithic populations having low fertility and high mortality at young adulthood might not be right. However, the results only reflects that specific population, and we should not make the same mistake as previous scholars have and draw to big conclusions from single facts (Baitzel & Goldstein, 2016).

The Achilles heel of paleodemography is the ageing of older adults. The methods have been mentioned earlier and they are heavily disputed whether they are reliable or not. Most methods have the ability to determine an approximate age up to 50 years, some stop at 20 years and some are heavily influenced by age mimicry (Gurven & Kaplan, 2007). Paleodemographic studies have historically calculated longevity and senescence based on the data provided by these methods, however often it is difficult to distinguish a 50 year old from a 70- or 80 year old (Page & French, 2019). The fertility patterns have been interpreted by these data as well, skewing mortality curves negatively. Apart from improving the methods of paleodemography regarding ageing, it is also necessary to make the field more approachable in order to better make people understand the science and being able to contribute to it. Howell (1986) pointed out that by removing and replacing highly technical or unclear vocabulary, it might make paleodemography much more attractive to researchers, since the science really is not that advanced, even though it might sound like it. Howell (1986) describes the posh vocabulary as somewhat of a castle in the air produced only for the ego of the reseacher. With the rise of the Rostock manifesto and the transitional analysis and the possibility of producing more accurate age-at-death profiles, the whole field of paleodemography is shifting and previous data is discarded and recalculated and the image of past populations is changing. Until a method for counting "tree rings" in bone has been developed, TA3 seems to be a reliable and accurate alternative for assessing age in old adult individuals. Althought TA3 needs to be further tested and evaluated is has shown great promise and might be revolutionary for the field. So, instead of bidding farewell to paleodemography, the time has come for us to welcome it back and look forward to all it has to bring in the following decades.

8. Conclusions

Paleodemographic studies investigate the dynamics between fertility, mortality and mobility in order to estimate prosperity and development in ancient populations. These processes are incident to establishing age and biological sex of the involved individuals. Traditional age estimation methods used in bioarchaeology and forensic pathology has long been known to produce inaccurate age estimations in older adult individuals, and by extension, in populatory studies. Transition Analysis 3 adresses the issue with traditional age assessment methodology and has proven to being a useful tool for estimating age in all adult individuals, including the very old ones. TA3 is not dependent on any single skeletal trait, but is instead a multitrait instrument, making it advantageous assessing taphonomically challenged individuals. The skeletons from S:t Nicolai cemetery had varying degrees of preservation, making the material well suited for the purpose of testing the third version of TA3. The results from the TA3 analysis indicate that the method holds increased opportunities in detecting older ages in populations than traditional methodology. Previous research based on traditional age estimation methods has had difficulties detecting individuals over the age of 50 years old (Milner & Boldsen, 2012; Bullock et al., 2013; Clark et al., 2019). By using TA3, 56 % of the entire population was estimated of being older than 50 years when they died. For traditional age estimation, age ranges increase with rising age, however, for TA3, the age ranges decreased. When the standard deviations for the most commonly used traditional age assessment method were compared to TA3, the results showed variation, however, the standard deviations for the older adult ages were significantly smaller for all skeletons except the very poorly preserved ones, further research on this aspect is therefore recommended. The main issue using TA3 is the absence of, and need for inclusional guidelines for extensive age ranges without compromising the reliability of the method. The results further present the High Medieval population from S: t Nicolai cemetery as deviating from similar contemporary paleodemographic studies. The demographic overview of the individuals clearly presents an unnatural population with an uneven distribution in favor of male presence combined with a complete absence of young children. Representation in older adult ages is high, following more natural mortality patterns than previous research, however, whether this is the sole effect of using the TA3 method or also is the consequence of socioeconomic prerequisites is unclear. Further paleodemographic studies of other High Medieval cemetaries is needed in order to establish the full effect of using Transition Analysis 3 in paleodemographic studies. TA3 as a tool for assessing age in adult population has proven to be very useful due to the fact that only two traits are needed in order for an estimate point with accompanying age range to be performed. The method's ability to detect older ages in adult populations fundamentally transforms paleodemographic previous assumptions and ideas. TA3 produces revolutionary results for age assessment and it's future developments and progresses in paleodemographic research will be intriguing to follow.

9. Ethics

In the last decade, age assessment methods have gained greater interest because of the increase of asylum applications in Europe due to the Syrian war. The methods previously and almost exclusively used by archeologists, anthropologists and forensic pathologists now were of interest for political reasons. Several methods also quickly developed using radiography to investigate dental eruption and epiphyseal fusion along with statistical modelling to estimate ages for people that might have their lives depending on these results. It is crucial when using and developing these kinds of methods that all research remain completely transparent and that there is full disclosure of methodology and calculations as well as raw data in order for other researchers to detect errors and further develop the methods so that there is no doubt that there are no political underlying agenda present (Arge et al., 2020).

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