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## Health, cattle and ploughs

Bioarchaeological consequences of the Secondary Products Revolution in southern Sweden, 2300-1100 BCE

Tornberg, Anna

2018

*Document Version:*

Publisher's PDF, also known as Version of record

[Link to publication](#)

*Citation for published version (APA):*

Tornberg, A. (2018). *Health, cattle and ploughs: Bioarchaeological consequences of the Secondary Products Revolution in southern Sweden, 2300-1100 BCE*. [Doctoral Thesis (compilation), Department of Archaeology and Ancient History].

*Total number of authors:*

1

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ACTA ARCHAEOLOGICA LUNDENSIA  
Series altera in 8°, no 71

# Health, cattle and ploughs

Bioarchaeological consequences of the Secondary Products  
Revolution in southern Sweden, 2300-1100 BCE

ANNA TORNBERG

DEPARTMENT OF ARCHAEOLOGY AND ANCIENT HISTORY | LUND UNIVERSITY

STUDIES IN OSTEOLOGY 5



# Health, cattle and ploughs

## Bioarchaeological consequences of the Secondary Products Revolution in southern Sweden, 2300-1100 BCE

Anna Tornberg



**LUND**  
UNIVERSITY

DOCTORAL DISSERTATION

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University, Sweden.

To be defended in room C121 at LUX, Lund University. Friday 11<sup>th</sup> May at 13.15.

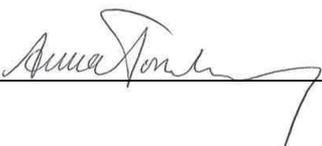
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<b>Organization</b> LUND UNIVERSITY Department of Archaeology and Ancient History Pb 117 SE-221 00 Lund SWEDEN		<b>Document name</b> DOCTORAL DISSERTATION	
		<b>Date of issue</b> May 11, 2018	
<b>Author(s)</b> Anna Tornberg		<b>Sponsoring organization</b>	
<b>Title and subtitle</b> Health, cattle and ploughs: bioarchaeological consequences of the Secondary Products Revolution in southern Sweden, 2300-1100 BCE.			
<b>Abstract</b> <p>In this thesis diet and health of people who lived in southern Sweden 2300-1100 BCE is studied. The study is based on bioarchaeological analyses of human remains from 46 localities in the areas of Uppland, Närke, Östergötland, Västergötland, and Scania. The studies are based on skeletal remains from a minimum number of 310 individuals that have been analysed both osteologically and biochemically. The thesis constitutes five papers and a synthesis, in which diet and health, related to agro-pastoral intensification and increased social stratification, is explored and discussed.</p> <p>The author acknowledges a biocultural approach, i.e. human biology and culture are intertwined and affect each other. A variety of cultural expressions and actions form human biology, which can be studied as skeletal adaptation or stress. This relationship makes it possible to study past cultural behaviour through analyses of human skeletal remains. The results of the papers have been discussed in relation to bioarchaeological theories and methodologies as well as current regional archaeological understandings.</p> <p>The period around 2300-1100 BCE is considered by archaeologists as a period of agro-pastoral intensification, population increase, and increased social stratification. Agro-pastoral intensification allows for increased access to nutrition, and further, a resource surplus. This development would plausibly also result in population increase and increased socio-economic differences. Through investigations of diet, oral health, stature, paleopathology and care, mobility, and demography insight in the biological consequences of this development have been gained.</p> <p>The results from the papers show that there is a higher reliance on cereals and cattle in the Late Neolithic-Early Bronze Age than in previous periods, which is visible both in stable isotope results and the frequency of dental caries. The health of the population seems to have been generally good with high stature, low prevalence of pathological lesions related to nutritional stress, possibility of gaining care if injured, many surviving into old ages, and low child mortality, which is indicative of low risk of infections due to low population density. However, an elevated risk of dying as young adults and decreasing female stature in the Early Bronze Age might reflect increased levels of stress in parts of the population.</p>			
<b>Key words</b> Late Neolithic, Early Bronze Age, southern Sweden, bioarchaeology, care, health, dental caries, biocultural, political-economy, Secondary Products Revolution, paleopathology, paleodemography, stature, trauma, human osteology, isotopes			
<b>Classification system and/or index terms (if any)</b>			
<b>Supplementary bibliographical information</b>		<b>Language</b> English	
<b>ISSN and key title</b> 0065-0994 (Acta Archaeologica Lundensia Series Altera in 8°) 1654-2363 (Studies in Osteology)		<b>ISBN</b> 978-91-88473-85-1 (print) 978-91-88473-86-8 (electronic)	
<b>Recipient's notes</b>	<b>Number of pages</b> 319	<b>Price</b>	
	<b>Security classification</b>		

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Printed in Sweden by Media-Tryck, Lund University  
Lund 2018

Coverphoto by Anna Tornberg

English revised by Sarah Hussell

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Joint Faculties of Humanities and Theology  
Department of Archaeology and Ancient History

ISBN 978-91-88473-85-1 (print)

ISBN 978-91-88473-86-8 (electronic)

ISSN 0065-0994 (Acta Archaeologica Lundensia Series Altera in 8°)

ISSN 1654-2363 (Studies in Osteology)



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*To Greta and Stina*

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## Acknowledgements

There are so many people and organizations that in various ways have contributed to the writing of this thesis and to whom I want to direct my sincere gratitude. I could not have written this thesis without the contribution of any one of you!

First of all, I would like to thank my main supervisor, Torbjörn Ahlström, for genuine interest in my work and much appreciated guidance along the way. It has been fun discussing stature, demography and the Neolithic in general! I would also like to thank my co-supervisor, Hans Christian Petersen, for your immense knowledge and your help regarding the use of statistics.

Working through numerous boxes with commingled skeletal remains takes time. A great thanks to Torsten Söderberg's foundation for financially supporting the additional time to finish this thesis. This thesis is based on both osteological and biochemical analyses. Biochemical analyses are expensive and this research could not have been carried out without financial support. Thank you to the Berit Wallenberg Foundation, Kungliga Fysiografiska sällskapet in Lund, the Ebbe Kock Foundation, Bruzewitz Foundation, the Per Westling Foundation, the PhD Uno Otterstedt Foundation, the Bokelund Foundation and Kungliga Vitterhetsakademien for financing stable isotope analyses, radiocarbon dates, transportation of bone material, and travels necessary for this thesis. Thank you also to the research project "The Rise" for permitting me to publish radiocarbon dates conducted within the project.

When ambition and ability do not fully correspond the expertise of others is so valuable. Thank you to my co-authors Malou Blank, Corina Knipper and Lars Jacobsson for your expert knowledges and for wanting to work with me. Malou, your ambition and energy impress me! I had so much fun working together with you and I look forward to future collaborations! Corina, thank you so much for your excellent comments in general and expert knowledge on strontium isotopes in particular! Lars, dad, thank you for engaging in our paper even though it is so far from your ordinary work. Thank you for providing your expert knowledge on the neuropsychological and neurophysiological effects of skull trauma. Thank you for going along with your daughter's curiosity! Thank you also to Karl-Göran Sjögren for

important comments on Paper III. Thanks also to Inger Sjunnesson, Lena Strid and Sarah Hussell for valuable proof-editing and language revision.

Thank you to Leena Drenzel at the Swedish History Museum for receiving me at the museum storage in Tumba and for helping me with the loan of a huge amount of bone boxes. Thanks also to Jan Storå for giving me the opportunity to measure long bones at the Osteological Research Laboratory in Stockholm. A great thanks to the staff at the Historical Museum at Lund University for all the help with finding lost bone boxes and providing me with a great working place for a whole year. A special thanks to Jenny, Lovisa and Anders for always making me feel welcome at the museum storage, and for all the laughter and vast amounts of coffee.

Writing a thesis is not all work, there is room for some play as well. Thank you to all of my fellow PhD students over the years for much laughter, coffee, and stimulating (and funny) talk. Thank you Johanna, Maria, Mattias, Mikael, Katarina, Lovisa, Sian, Anders, Andreas S., Johan S., Johan V., Susan, Peder, Fanny, Hampus, Valentina, Anna-Stina, Kenth, Janne, Lena, Danilo, and Gertie. Helene, thank you for being a mentor during my first year. Thank you for all the sharing and all the caring! Thanks Helene for all stimulating discussions and nerdiness about pathologies and human osteology in general and for all your kindness over the years. Things would have been a lot more difficult without you! Stella, Ylva and Adam, thank you for interesting talks about bones, archaeology and many other things. Thank you also for comments on manuscripts and being generally awesome osteologists, colleagues and friends! Andreas N., we have followed each other in academia for over 10 years now, first as students and later as roommates in our PhD studies. Thank you for putting up with my Gothenburg jokes for over six years and for all the recipe exchanges. Where should we go from here?

Thanks to all the other fantastic colleagues at the Department of Archaeology and Ancient History, for often weird but funny conversations over coffee. Thank you Kristina Jennbert for your genuine interest and support in my research. Many thanks also to Debbie Olausson for good inputs to improve manuscripts and research ideas. I'm grateful to Elisabeth Iregren for always showing up at seminars and for making osteology so very interesting when I first started as a student. Thank you Ola Magnell for help with finding zooarchaeological materials and for valuable comments at seminars. Thanks to Caroline Ahlström Arcini for interesting bone conversations over the years. Thank you to Lars Larsson for initiating the Scanian Neolithic Research Group and to all of the group members for valuable exchanges and

interesting field trips. Jan Apel put a lot of time and effort into reading and commenting on an early draft of the thesis synthesis and functioning as an opponent at my last seminar. I am very happy to have had an opponent with such in-depth knowledge of the Late Neolithic. Björn Nilsson, despite already being pre-occupied with many other projects, agreed to read the final draft of this thesis. Thank you! I am very happy and grateful for both of your valuable comments to improve the end product.

Finishing a thesis is not done only within the walls of the university but tends to include family and friends in different ways. I want to direct the gratitude to mom for eating oranges with me on the Iron Age barrow in Hällfors as a child. This made me curious of life in the past and planted a seed to become an archaeologist/bioarchaeologist. Thank you to dad for being a source of inspiration and security, and for agreeing to co-author with me on one of the papers. Both of you have always been supportive of my choices and I thank you both for all the encouragement through the years. Thank you Anki for always caring, listening, and for being such a wonderful person in general. You have the biggest of hearts. To my siblings and their families – thank you for finding an interest in what I do and for being supportive in all kinds of ways. I'm so grateful for all of you, big and small.

Inger and Adler, thank you for being the best in-laws one can think of! Thank you especially for all of the help with child care when needed and for always being interested and supportive. This gratitude is also directed to Martin.

I also want to thank all of my friends, both near and far, who have been there through the years, cheering on, and who have found (in different degrees of self-selectness) an interest in bioarchaeology. You know who you are, and I hope to find more time for you now when this thesis is finished!

The six years under which this thesis has progressed have been the most important ones in my life. During these six years I got married to a wonderful man and have given birth to two fantastic and strong daughters. Patrik, thank you for always believing in me and for being my best friend for almost 14 years. It's time for new adventures! Greta and Stina, you are extraordinary intelligent and fun-loving children. Thank you for bringing more energy and laughter to our family. I love all of you so very much!

Anna Tornberg

Lund, March 2018



# 1. Introduction

Skeletons provide unsurpassed information about living, and sometimes dying, in past populations. Archaeologists attempt to gain knowledge and understanding of past societies and cultural behaviour. Culture is created and upheld by living people, and societies are comprised by them. Therefore, direct studies of skeletal remains give insights into living and dying on an individual level, as well as on cultural behaviour and past societies on a macro scale. Human biology is codependent on culture. The skeletons that are analysed were once living and formed the society in which they lived; in turn, society formed the individuals, both biologically (nutrition, health, and activity) and in terms of identity. This biocultural approach is the foundation of bioarchaeological research. Biology and culture are inherently intertwined and affect each other. This view is further developed in section 2.2.1.

In this thesis I use a bioarchaeological approach to examine health in the south Swedish Late Neolithic (LN) and Early Bronze Age (EBA) (c. 2300–1100 BCE) (Montelius, 1885, 1917; Vandkilde, 1996). The LN is considered as the starting point towards the socially stratified Bronze Age, where an egalitarian society emerged into a warrior elite (e.g. Holst et al., 2013; Kristiansen, 1998, 1999; Kristiansen and Earle, 2015; Kristiansen and Larsson, 2005; Earle, 1989, 2002; Earle et al., 2015; Vandkilde, 1996). Different scholars highlight the importance of different events and reasons for this transition, seeking answers in either an intensification of agriculture (the Secondary Products Revolution) (Sherratt 1981, 1997, 2004; Earle, 1989) or the adoption and distribution of metals (Vandkilde, 1996; Kristiansen and Earle, 2015), especially when it comes to triggers for social hierarchies. The LN is often seen as a transitional phase between the Neolithic and the Bronze Age (Stensköld, 2004, p. 11), which is perhaps mirrored in the terminology where the LN lacks a name related to cultural expressions, such as those present in the Early Neolithic (EN) and Middle Neolithic (MN) (e.g. Funnelbeaker culture and Pitted Ware culture). Previous research on the LN and EBA has primarily been conducted through traditional archaeological methods with the foundation in the humanities. In

recent years, new research focusing on the formation of a Bronze Age society, with methods from the natural sciences, has emerged in south Scandinavian archaeology, especially through the research project “The Rise” at Gothenburg University. This project has primarily focused on migration and mobility through studies of aDNA and strontium isotopes, but research related to diet and health has not been included and is thus needed. Intensification of agriculture, as well as differences in social (economic) status, is likely to influence physical health. Health is a holistic term, in which both physical and psychological wellbeing is considered, as well as experienced health. Experienced health is referring to an individual feeling of being healthy or unhealthy and does not necessary correspond to physiological wellbeing. While bioarchaeologists have traditionally worked only with (parts of) physical health, I attempt in this thesis to broaden the concept of health in bioarchaeological research to also encompass a discussion about the social consequences of physiological and cognitive dysfunction.

My curiosity has always been awakened primarily by the large questions, often with an orientation towards subsistence and politics. This is true regarding both my research and in everyday life. These large questions are often accompanied by questions of development and transition, which also make up the frame of this thesis.

## 1.1. Aims and research questions

Throughout the history of archaeology, theoretical approaches have been fluctuating, sometimes discussing large-scale prehistoric events and at other times only focusing on in-depth approaches to smaller topics, such as individual settlements, etc. The research focus of the LN and EBA has traditionally been on habitats, first through the distribution of graves (e.g. Malmer, 1962; Oldeberg, 1974) and later through settlements (Gröhn, 2004; Artursson, 2009; Artursson et al., 2010; Brink, 2013), and artifacts, especially with a focus on craft (Olausson, 2000; Apel, 2001; Bergerbrant, 2007). Burials have also been of research interest (Håkansson, 1985; Olausson, 1993; Weiler, 1994; Stensköld, 2004), although not in relation to the individuals buried and the skeletal remains; instead, the burial research has primarily focused on identities and hierarchies based on prestige goods and the monumental grave form. Up until now, the skeletons have been left

unexplored, but, here, they will serve as the foundation of this thesis. I believe that there are a few main reasons for this. First of all, much of the skeletal material is associated with excavations that were conducted in the early twentieth century, which makes the documentation often of poor quality or even lacking entirely. Secondly, historical osteology is a relatively young discipline in Sweden. Thirdly, there are difficulties in relative dating of the different burial types, making a large quantity of expensive radiocarbon dates a necessity. However, the bone quality from the early excavations is excellent, providing a good basis for osteological analyses. Although different burial types are both unequally easy to find due to being visible or invisible in the landscape and allow different possibilities for bone survival, the skeletal remains themselves are a unique source material that do not discriminate or disqualify any social level, and which have the potential to include all people who were once living. The previous negligence of the osteological material has resulted in a focus on power and prestige items, which are more easily detectable through the archaeological records, but have generally failed to find, or been uninterested in, ‘commoners’ and evidence of daily life. I use the term ‘commoners’ in this thesis to distinguish between groups of individuals associated with high status graves and individuals buried in non-monumental graves with low amounts of bronzes. The term could also be farmer or agro-pastoralist but these terms do not fully encompass socioeconomic differences. The advances and new methodology within contract archaeology have, in the last two decades or so, provided new and valuable knowledge about the Neolithic and Bronze Age in southern Sweden, especially regarding settlements. The large excavations related to the constructions of the Öresund Bridge (“Öresundsförbindelsen”/“the Öresund connection”) in the late 1990s–early 2000 and of a train tunnel in Malmö (“Citytunnelprojektet”/“City tunnel project”) in the early 2000s have played big parts in this construction of knowledge.

The lack of ‘commoners’ in previous archaeological research has sometimes been explained by a cultural habit of not burying all of the dead, but this theory has been disproved by recent research (Bergerbrant et al., 2017). The research conducted within this thesis provides new and valuable knowledge of life and death in the LN and EBA which had previously been left unstudied. The aim is to target smaller topics connected to human biology and health, providing important pieces in large archaeological debates on the effects of the Secondary Products Revolution (Sherratt, 1981, 2004) and the rise of Bronze Age society.

The aims of this thesis are:

- i.) To evaluate diet, subsistence, and possible dietary variations in the LN and EBA;
- ii.) To provide evidence for health, health changes, and care in Neolithic and EBA southern Sweden using a holistic approach;
- iii.) To model a paleodemographic profile for LN–EBA southern Sweden;
- iv.) To address past social relations using bioarchaeological methods.

These four aims give insight into biological changes related to intensification in agro-pastoral subsistence and the development of Bronze Age society. The aims are explored in five articles through the following research questions:

- Is the heterogeneity of burial customs traditionally associated with the south Scandinavian LN and EBA (inhumations in flat burials, gallery graves, and barrows) related to a difference in chronology, and are there differences in dietary isotope values between individuals buried in these different grave types that cannot be explained by chronology?
- Is there a change in stature in the transition to agriculture and within the Neolithic–Bronze Age period?
- Is there any bioarchaeological evidence of population increase, higher mobility, changes in subsistence, and increased nutritional access in the LN megalithic grave population compared to the MN megalithic grave population in Falbygden (where this study was carried out)?
- To what extent does the demographic model, which is based on a skeletal population from the south Scandinavian LN–EBA, correspond to comparative populations? Does the demographic model correspond to a stipulated population increase in the LN–EBA?
- Has the use of transition analysis made it possible to find individuals of an age higher than 50 years in the LN–EBA population? To what extent does the demographic model, based on a skeletal population from south Scandinavian LN–EBA, correspond to the comparative populations? Which stressors might have affected the demographic profile of the south Scandinavian LN–EBA population?

The papers are summarized in chapter five.

## 1.2. Outline

This thesis is a compilation thesis that comprises five research articles and a synthesis (Sw. *kappa*) where the results from the articles are further developed and discussed. The articles function as sub-studies for the research aims of this thesis but also stand alone as individual contributions to a specific field of research. The synthesis gives an overview of the research undertaken in this area so far and a general archaeological background of the LN-EBA in southern Scandinavia. It also contains a deeper discussion of the results of the paper in relation to the research aims and a general summary of the papers. The thesis is structured as follows:

- A background comprising research history, theoretical departure, and an archaeological background (chapter two);
- Material descriptions (chapter three);
- Descriptions of the different methods that have been applied (chapter four);
- Summaries of the five papers (chapter five);
- A discussion of the results in relation to the aims and research questions (chapter six);
- Conclusions (chapter seven);
- Archaeological implications (chapter eight);
- Summary in Swedish (chapter nine);
- The research articles.

### 1.2.1. Author contributions

The majority of the articles are written only by me. However, two of the articles are co-authored. I therefore present the author contributions of all papers below:

**Paper I:** “Diet, Toothache and Burial Complexity. Tracing Social Status through Bioarchaeological Methods in Late Neolithic–Early Bronze Age Scania.” *Lund Archaeological Review* 22 (2017).

This paper is written without a co-author.

**Paper II:** “Stature and the Neolithic Transition– Skeletal Evidence from Southern Sweden”. *Journal of Archaeological Science: Reports* (2018).

This paper is written without a co-author.

**Paper III:** “New Perspectives on the Late Neolithic of south-western Sweden. An interdisciplinary investigation of the Gallery Grave Falköping stad 5”. *Open Archaeology* 4 (2018).

This paper is co-written with Malou Blank, Gothenburg University, and Corina Knipper, Curt-Engelhorn-Center for Archaeometry in Mannheim.

*Anna Tornberg:* osteological analysis; production of sections related to osteology; demography and paleopathology (methods and results).

*Malou Blank:* Statistical analyses of isotopes and radiocarbon dates; production of sections related to biochemistry and archaeology (methods and results); production of the archaeological background section.

*Tornberg and Blank, joint work:* sampling for biochemical analyses; production of introductory chapter; discussion chapter; conclusion chapter.

*Corina Knipper:* production of section regarding Sr-isotope methodology; manuscript commenting.

**Paper IV:** “The paleodemography of Late Neolithic–Early Bronze Age agropastoralists from southern Sweden.” Submitted to *Open Archaeology*.

This paper is written without a co-author.

**Paper V:** “Care and Consequences of Traumatic Brain Injury in Neolithic Sweden: A case study of ante-mortem skull trauma and brain injury addressed through the bioarchaeology of care.” *International Journal of Osteoarchaeology* (2018). <https://doi.org/10.1002/oa.2646>.

This paper is co-written with neuropsychologist Lars Jacobsson (PhD), Sunderbyn and Kalix hospitals, Luleå Technological University, Lund University.

*Anna Tornberg:* Archaeological background; osteological methodology; index of care introduction; osteological and archaeological results.

*Lars Jacobsson:* Neuropsychological background; neuropsychological considerations (results).

*Tornberg and Jacobsson, joint work:* Discussions of implications of trauma and care; conclusions.

## 2. Background

There are almost as many bioarchaeologists or historical osteologists as there are bioarchaeologies or historical osteologies. The terminology of archaeologists specializing in bones differs across regions, time, and even universities. The approach to a material also differs among researchers. There are researchers who are mainly interested in methodological development and there are others who rather seek to use these developments to answer archaeological problems. All of these researchers fit under the same umbrella of bioarchaeology. Since this discrepancy in approaches exists, scientific transparency is of great importance. I have a background in both prehistoric archaeology and historical osteology which makes this thesis oriented more towards archaeological questions than towards advances in bioarchaeological methodology. In this chapter, I will give a background to bioarchaeology and the Neolithic transition and to the Neolithic in general, outlining the Swedish situation in more detail. I will also introduce the theoretical framework and point of departure for this thesis. Considering that this thesis should be seen in relation to discussions within traditional prehistoric archaeology, I also provide an archaeological background to the LN–EBA in southern Scandinavia.

### 2.1. Theoretical approach

According to Cambridge Dictionary Online, archaeology is “the study of the buildings, graves, tools, and other objects that belonged to people who lived in the past, in order to learn about their culture and society.” I believe that this is a description that many archaeologists would consider too technical, and that it misses out on the most important part—the humans themselves. As a discipline within the humanities, archaeology might be better explained as the study of being human in different cultural contexts through observations of their material culture. Bioarchaeologists, on the other hand, focus their study on the remains of the actual individuals that lived in this

past, not their artifacts. The aim of bioarchaeological research can either be to study the individuals themselves – knowledge of diets, activities, or health, for example – or it could be to study the society and cultural settings in which these individuals lived, where the knowledge of diets, activities, and health is put in perspective and interpreted from questions of ‘why?’ and ‘how come?’.

The terminology of bioarchaeology developed differently in the United Kingdom and in the United States. The terminology in the UK mostly developed from the terminology used by Graham Clark in relation to faunal remains from the excavations of Star Carr (Clark, 1972) while the US terminology developed from physical and biological anthropology and involved work on human remains (Buikstra and Beck, 2017, p. xviif). Buikstra (1977) emphasized a multidisciplinary approach with a focus on solving anthropological research questions including topics of diet and paleopathology, paleodemography, social organization, and activity (Buikstra and Beck, 2017, p. xviii).

From the mid-nineteenth century, the main concern of physical anthropology had been that of morphological comparisons between groups of humans, often termed “race” (Martin et al., 2013, p. 26). Research with a focus on “race” has also been practiced to a significant extent in Sweden, with the establishment of the Swedish State Institute for Racial Biology in Uppsala in 1922, with Herman Lundborg as its first curator (Broberg, 1995). Physical anthropology developed into biological anthropology when the understanding of physical differences as being the results of different races evolved to an understanding of physical differences being a result of cultural, ecological, and geographical variations (Martin et al., 2013, p. 30). A paradigm shift in the 1950s changed biological anthropology from having an interest primarily in racial and typological descriptions towards a biological anthropology primarily focused on populations, based on models of evolution and human adaptation (Zuckerman and Armelagos, 2011, p. 18). Within this new paradigm the biocultural approach in biological anthropology was born. Bioarchaeology has evolved from these biocultural branches within the discipline of biological anthropology. From being primarily descriptive prior to the 1960s, a bioculturally oriented modern bioarchaeology focuses on the bodily effects of social, environmental, and political processes (Zuckerman and Armelagos, 2011, p. 20). *Biocultural Adaptation in Prehistoric America*, edited by Blakely (1977), is the result of a symposium of the Southern Anthropological Society in Atlanta 1976, where scholars (mainly biological

anthropologists) united on the question that humans do not survive through biological adaptation or cultural adaptation, but through biocultural adaptation (review in Bass, 1978). The authors of the volume stressed the importance of collaborations between fields (archaeology, biological anthropology, ethnology, and others), as well as the documentation of ways that biological anthropology can contribute to the studies of cultural processes and the interrelationship between biology and culture (Bass, 1978). It is also within this publication that Buikstra (1977) defined her multidisciplinary bioarchaeology. In bioculturally oriented bioarchaeology, there is a belief that different aspects of culture (social organization, identity, subsistence, etc.) affect human biology in both positive and negative ways and that this can be studied through osteological and biochemical (i.e. bioarchaeological) analyses (Zuckerman and Armelagos, 2011, p. 21).

To move forward with my perception of bioarchaeology a distinction in terms of terminology is necessary. The term *interpretation* is widely accepted as a fundamental part of scientific research within the humanities; however, it is excluded from most research within the natural sciences. Much bioarchaeological research is based on methodologies developed within the natural sciences, but bioarchaeology as a discipline is concerned with questions about people and populations, thus being within the humanities. This is the reason that the “hard data” extracted from methodologies within the natural sciences needs contextualizing within (bio)archaeological theories. It seems as if there is a fear of interpretation within some scientific habitus in bioarchaeology at the same time as there is a fear of natural science within some scientific habitus in interpretative archaeology. Kristian Kristiansen recently wrote about this schism within the archaeological field. He put forward that the inclusion of results from the natural sciences could, in fact, help archaeological interpretations to take a big leap, and consequently would broaden archaeological theory and methodology (Kristiansen, 2017), despite the fear often present within interpretative archaeology that the opposite would be the case. The results from natural science need archaeological interpretation to make sense. My sincere position is that bioarchaeological research without attempting interpretations of the results is pointless; bioarchaeological research without interpretation of results would regress to the descriptive phase abandoned 50 years ago. What I mean by *interpretation* is a reasonable explanation of the results of an analysis in light of previous knowledge and theory. The interpretation of the human skeleton in the archaeological contexts is, to some extent, made hermeneutically, where focus shifts between the parts (a pathology, diet,

skeleton) and the whole (skeleton, archaeological context). The bioarchaeological framework, upon which this thesis rests, is developed from both osteological and archaeological knowledge. The two subgroups of bioarchaeology are dependent on each other and could not be separated. Excavated skeletons are remnants of the people once living in the time frame studied, giving a unique testimony of the time per se.

Bioarchaeological research could be both multidisciplinary and interdisciplinary. Wilhelmson (2017a) stresses the interdisciplinary (in contrast to multi-disciplinary) approach in bioarchaeology, and the importance of a developed theoretical foundation allowing interpretation, propagating for a human-centred archaeology. I do agree in much of Wilhelmson's emphasis on a human-centered archaeology, however, I believe that the interdisciplinary approach that she seeks does, in fact, fall inside the borders of bioarchaeology. She proposes that bioarchaeology as the archaeology of life is not enough, but that the archaeology of death should be included too (including peri- and post-mortem changes, intentional and unintentional) (Wilhelmson, 2017a, p. 34ff). This approach she terms *human-centred archaeology*. As much as I agree with Wilhelmson about the importance of interdisciplinary approaches and interpretations, as well as most of what she puts into her human-centred archaeology, I do not believe that there is a necessity for new terminology. Wilhelmson interprets the term *bioarchaeology* as the archaeology of life (deriving the term bio- from, e.g., biography), however, I claim that *bio-* in bioarchaeology is rather referring to biology or life in a wider perspective, which I exemplify below. This is also supported by biological anthropologist Kristina Killgrove, who defines bioarchaeology as: "the study of the human bodies of past cultures" (Oxford Bibliographies: Bioarchaeology) and further:

"By blending archaeology, biology, and cultural anthropology with theory and methods drawn from sociology, demography, chemistry, statistics, history, and forensics, among others, contemporary bioarchaeologists bring a multidisciplinary perspective to the past 10,000 years of humanity." (Oxford Bibliographies: Bioarchaeology).

In the first definition, Killgrove mentions neither life nor death, only bodies of the past. Thus, Killgrove's definition of bioarchaeology also includes the parts (including interpretations) that Wilhelmson calls for. The exception is that Killgrove formulates bioarchaeology as being multidisciplinary, while Wilhelmson emphasizes an interdisciplinary science (Wilhelmson, 2017a, p. 39). I agree with Wilhelmson. Wilhelmson's human-centred archaeology,

including bioarchaeology, is interdisciplinary, not multidisciplinary (or at least should be) since both approaches include a uniform terminology as well as an understanding of all methods applied, and further a joint theoretical framework. Also Martin et al. *Bioarchaeology: An Integrated Approach to Working with Human Remains* (2013) includes sections about taphonomy and the buried body. It is from this bioarchaeology I take departure. As Sofaer (2006) acknowledges, the living and the dead body is the same. Although analysing death and the dead body without inferring any interpretations of biological modifications/alterations during life, bioarchaeologists are still interested in understanding and interpreting life and the living. Even though taphonomical processes and the moment of death itself are the subjects of study, the main reasons for studying these concepts are to understand the cultural setting in which the dead body originated, i.e. among the living. This field of research has been explored under the labels of *Anthropologie de Terrain* or *Archaeoethanatology* (e.g. Duday and Guillon, 2006; Duday et al. 2009), where analyses of the skeleton are related to taphonomic processes such as decomposition. This kind of information is important in order to successfully discuss the dead body and burials in both archaeological and forensic sciences and has also been proceeded in a joint conference publication (Boddington et al., 1987). Another example of this kind of approach is the doctoral thesis by Stutz (2003) who used taphonomic methodology to analyse Late Mesolithic burials from Skateholm in Scania from a ritual perspective.

### **2.1.1. Bioculturally oriented bioarchaeology and a political-economic approach**

Archaeologists seek answers to questions in the past through material culture. Material culture can be seen as manifestations of human acts, both sacral and profane. Human activity results in specific material cultures that archaeologists find through excavations and interpret through theoretical models. The human body could likewise be considered as departure of interpretations of culture in the past. Traditionally, the body is considered natural in the dialectic relationship of nature and culture (Sofaer, 2006, p. 52ff) and osteologists have primarily functioned as experts providing data for archaeologists to interpret (Sofaer, 2006, p. 17). Sofaer speaks of the *body as material culture*. While I believe that she has a point in viewing the dead body as material culture in the respect that the body is intentionally, and unintentionally, affected by both the environment in which the living person

lived and died and the cultural behaviour practiced within this environment, Sofaer's approach tends to neglect evolutionary changes that are not related to cultural behaviour, at least in her terminology. Here, a bioculturally oriented bioarchaeology includes all agents that could affect skeletal adaptation: genetics, environmental and climatic responses, and reflections of social influences (Zuckerman and Armelagos, 2011, p. 18), to mention some. This means that a biocultural approach could also include theories of gene-culture co-evolution, i.e. the relationship where the genetic composition is affected by cultural habits at the same time as cultural habits are affected by genes (Durham, 1991). As such, bioarchaeology encompasses a rather wide definition and can include a variety of source material and methodologies (e.g. osteology and biochemistry). It is, however, mainly thought of as investigations of human remains. The term *bioarchaeology* says very little about theoretical approach and investigation aims; in practice, bioarchaeology can span from being practically absent of theory to being very heavy on theory. A bioculturally oriented bioarchaeology acknowledges that a variety of cultural expressions and actions form human biology and become visible to bioarchaeologists through the study of the skeletal remains in relation to other archaeological features. Thus, a reliance only on the skeletal remains is insufficient and must be interpreted in relation to other archaeological, anthropological, and ecological knowledge to become valuable. Taking this into consideration, areas as discrepant as economy and health can be studied through a biocultural (bio)archaeology, which is also done in this thesis. Economy and health are also interconnected. This approach deprives bioarchaeology from being a subdiscipline of archaeology and rather makes traditional archaeology a help-discipline of bioarchaeology. The roles have, in some regards, become reversed.

There are a number of economic theories that put forward different explanations of political-economic questions. However, I will not go into details of these theories in this thesis since these theories are based on more or less modern production and economy. When addressed in this thesis, political-economy should be regarded on a general plane as a term for the production and distribution of resources within the LN-EBA society. The effects of political-economic changes are examples of culturally influenced skeletal responses. Changes in production and distribution of resources could mean changes in, for example, nourishment and living conditions, which are known to affect health, and thus a kind of biocultural adaptation (Leatherman and Goodman, 1997). Changes in political-economy on a macro level could also affect socioeconomy on a micro level, thus generating differences in

wealth and social status between groups of people. When referring to prehistoric societies it might, however, be more relevant to refer to these kinds of differences as merely differences in social status and not include models that are based on modern economic systems. Studies of health and health differences could therefore illuminate both changes in political-economy and differences in social status. For example, studies of differences in stature have often been used as a marker of socio-economy (and as an effect of political economy), but the reasons for these differences have seldom been addressed (Leatherman and Goodman, 1997). The rise of political-economic research within bioarchaeology is related to the development of post-processual archaeology and the focus of social inequalities and social consequences of differences in economic production in past societies (Zuckerman and Armelagos, 2011, p. 18).

A bioculturally oriented bioarchaeology, with the theoretical focus on biological adaptations related to political-economic situations, is especially suitable in the cultural setting of the LN–EBA. A bioculturally driven bioarchaeology focuses more on patterns in the distributions of pathologies or other biological responses to culture, rather than on the presence, absence, or frequency of these pathologies and responses (Zuckerman and Armelagos, 2011, p. 20). The archaeological evidence strongly suggests a change in political-economy and a more socially and economically stratified society during this period. It is probable that a related increase in social differences would be reflected as skeletal adaptation, or stress, in these past populations. Adaptation is primarily addressed in relation to positive skeletal changes, and stress is the degenerative counterpart (Goodman et al., 1988). Studies of patterns of stress and adaptation could therefore function as a very informative way to study socio-economic inequalities. Zuckerman and Armelagos highlight the fact that bioarchaeology can reach further than traditional archaeology in analyses of socio-economic inequalities and political-economic changes since “*individuals cannot easily mask their biological responses to disease or malnutrition*” (Zuckerman and Armelagos, 2011, p. 20). A biocultural approach for studying changes in political-economy and differences socio-economy has previously been addressed by, for example, Bogin and MacVean (1978, 1983); Goodman et al. (1988); Bogin and Loucky (1997) Leatherman and Goodman (1997); Goodman (1998) and Leatherman (1996, 2005). It has also been applied in various ways throughout the work of this thesis and is approached through different angles in the five articles.

### **2.1.2. The bioarchaeology of affluence**

Many scholars report a decline in health related to malnutrition and increased morbidity following the Neolithic transition (see section 2.2.3.). Since the development of a Bronze Age society is considered intimately connected to food production surplus (Sherratt, 1981, 1997; Earle, 1989; Greenfield, 2010), the way in which both a surplus and a food shortage could be studied is of interest. What would the bioarchaeology of affluence look like?

Ervynck et al. (2003) divided food consumption into four different levels:

Level 1: What is physiologically necessary;

Level 2: What is considered to be the basic need (above strict physiologically demands);

Level 3: Affluence: consumption beyond basic and considered needs;

Level 4: Luxury: consumption beyond the level of affluence, of special goods or goods in limited supply, etc.

It could be said that the first three levels comprise the degree of nutrition and consumption in quantitative ways while level four rather refers to nutrition qualitatively (Ervynck et al., 2003). I consider studies of both level three and four as interesting in relation to the Secondary Products Revolution and the development of a Bronze Age society.

Considering the archaeological evidence it is reasonable to see a two-step development, one in the MN–early LN and one in the later LN–EBA. Considering that the first phase is connected to the Secondary Products Revolution and intensification in agro-pastoral activities, the first step would provide evidence for increased nutrition, thus affluence, and better health. The second step, on the other hand, would provide evidence for increased differences in nutrition and health within the population, so that parts of the population show evidence of good health following affluence and possibly luxury, while others show signs of malnutrition.

So, in terms of biology or health what is to be expected following affluence or luxury? The bioarchaeology of affluence could be analysed as the opposite of the bioarchaeology of poverty. In the bioarchaeology of poverty, different stressors and signs of malnutrition would be present (Leatherman, 1996, 2005; Goodman et al., 1988; Leatherman and Goodman, 1997). These stressors and signs would thus not be present in populations living in affluence. Since the level of affluence refers to a surplus in food in

quantitative matters, a bioarchaeological expectation would thus be a population with low amounts of pathologies connected to malnutrition, or at least undernutrition/starvation. A sufficient amount of nutrients would also be beneficial for health in general. Affluence and good health (i.e. step one) might be reflected in low frequencies of general stress such as linear enamel hypoplasia and cribra orbitalia but also high stature and a high proportion of individuals surviving into old ages. The agro-pastoral intensification associated with this step might also support decreased levels of vitamin D deficiency (rickets) and increased levels of dental caries. A good state of nutrition could include the majority of a population; the consumption of luxury foods, however, could not. Since luxury consumption does not refer to the quantity of food consumed, but to the quality, particularly in terms of exotica, the very nature of luxury consumption automatically excludes a large part of a population. If all of the population had access to luxury foods, these foods would no longer be deemed exotic, thus losing their luxury status. Luxury foods would probably not affect general health; however, the consumption of such goods could possibly be detected as differences in stable isotope composition for diet reconstructions between groups, or through differences in other bioarchaeological markers of dietary habits, such as dental calculus, dental caries, or tooth attrition. In step two, the features of step one would be present in one part of the population whereas the other part might suffer from higher frequencies of stress-related pathological conditions, lower stature, and increased risk of dying in younger years. On the other hand, a population increase that is a probable effect of agro-pastoral intensification might result in an increased risk of dying in young years for the entire population, as well as a higher child-mortality rate, due to increased risk of infectious disease caused by higher population density. The population density could further increase general stress indicators in the population as a whole.

It is evident that a bioarchaeology of surplus might be easier to detect than a bioarchaeology of political and economic differences. Hayden (1995) emphasizes that it is surplus and abundance, not strained resources, that lead to social inequality. Furthermore, following Hayden, a politically and economically stratified society would thus, at least initially, show bioarchaeological evidence of good nutrition and low frequencies of stress.

### 2.1.3. The problem of health

The World Health Organization (WHO) defines health as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity” (WHO homepage). Cambridge Dictionary, however, defines health as “the condition of the body and the degree to which it is free from illness, or the state of being well” (Cambridge Dictionary Online). The term *health* as defined by WHO is, of course, troublesome to infer in past populations since it is partly subjectively experienced, impossible to extract from dry bones. The definition by Cambridge Dictionary, on the other hand, is more readily applicable in bioarchaeology. The *American Journal of Physical Anthropology* (AJPA) devoted a special issue (2014) to raising questions about health and stress. Health and stress have long been used in parallel and synonymously in paleopathological studies (Temple and Goodman, 2014). However, Temple and Goodman (2014) wisely argue that stress indicators in skeletons derive from specific time periods during life and differ significantly from the levels of health within a population in the long term.

There is a variety of literature providing information and research on disease and paleopathological conditions (i.e. stress), methods, and problems within bioarchaeology (Aufderheide et al., 2011; Grauer, 2012; Roberts and Manchester, 2005; Waldron, 2009; Brickley and Ives, 2008; Tilley, 2015), but only few show interest in a more holistic approach to illness, care, and health, for example (Roberts and Manchester, 2005; Roberts, 2011; Tilley and Oxenham, 2011; Tilley and Cameron, 2014; Tilley, 2015; Tilley and Schrenk, 2017; Vlok et al., 2017). Judd and Redfern (2011) argue that the way forward for paleotrauma studies is to include a discussion about the association between trauma and disability, as well as the social consequences related to the injury. Roberts and Manchester (2005) further promote research of population *health* (my emphasis) rather than paleopathological studies on an individual level. Both of these approaches accentuate the meaning of illness for the society as a whole. To direct the discussion of sickness and health towards a population level and the meaning of health on a societal plane is also the intension of my thesis.

The first thing to acknowledge when working with a bioarchaeological approach to health is, that all of the individuals are dead and are therefore automatically not in good health. Instead, what we as bioarchaeologists/paleopathologists study is not a mirroring of a living population, but a biased version where individuals with the highest frailty in

their specific age-class die, which is discussed as selective mortality (Wood et al., 1992; Cohen et al., 1994; DeWitte and Stojanowski, 2015). Throughout this thesis I have intentionally left out frequencies of most paleopathological features and diagnoses. There are several reasons for this. The first reason is related to the nature of the skeletal material. The majority of the skeletal remains come from gallery graves with numerous commingled remains from a sometimes relatively large time span. There is no possibility of relating the bones to single individuals. Therefore, other important features known to reflect health (e.g. demography and stature) could not be integrated in the paleopathological analysis. The trouble of linking paleopathological bones to single individuals also makes diagnostic work very hard, if not impossible, since similar paleopathological features could have different etiologies that could only be diagnosed properly with additional information. Secondly, due to the commingled, fragmentary state of remains, I consider it impossible to address health on a population level from paleopathological features since I cannot take into consideration the possible frailties of individuals (hidden or based on sex or social status) due to the lack of specific individuals in my sample. To do so would be to neglect the osteological paradox (Wood et al., 1992), a theory I acknowledge. A third argument is that only analysing frequencies of different paleopathological features could not reflect health, especially when the former two arguments are considered. It is important to bear in mind that there are a limited number of pathologies that do affect the skeleton, but also that the pathology must be present in the individual for some time for the skeleton to actually display a pathological feature.

However, health in ancient societies is a very interesting field of research that can reveal important information about a society when discussed on a population level and not only on an individual-case basis. The papers upon which this thesis rests are examples of different ways to understand the health of past populations. I choose to use the term *health* consciously since I do not believe that either *paleopathology* or *stressors* are sufficient terms given the aim of this thesis. I have not been interested in investigating frequencies of different paleopathological characters or diseases in the LN–EBA, nor have I been interested in the disease or stressors themselves. I have had an interest in the people inhabiting southern Sweden during the LN and EBA: their lives, subsistence, and health. I am well aware that parts of the definition of health by WHO could never be assessed in osteological material. However, by integrating knowledge from modern medicine and psychology, a very important discussion about health and care in prehistory can be made. There

might generally be too little inclusion of qualitative data in bioarchaeological investigations. This view is further developed in section 2.1.3.1.

To get a broad and nuanced picture of health on a population level, different approaches to health and stress have been applied in the papers. I have included presence and absence of cribra orbitalia and enamel hypoplasia to consider possible physiological stress among individuals in a closed context in Paper III. These frequencies are related to other characters associated with health (stature and demography) in the population. Due to the commingled nature of the burials, I have not been able to assess the different characters to specific individuals, which is why influences of differences in frailty and selective mortality could not be considered in analysis, except as acknowledged. Stature throughout the Neolithic into the Bronze Age was investigated in Paper II. The long timespan provides very interesting insights into health changes over time. Demography was also evaluated and discussed in Paper IV, as well as in Paper III. These studies all aim to evaluate and discuss health and stress on a population level. I have also integrated a more holistic approach to health in Paper V where, in collaboration with a neuropsychologist, I have undertaken a study of the effects of severe skull trauma and a traumatic brain injury in an individual dated to c. 2300 BCE. Through these paleopathological studies, both quantitative data reflecting stress or non-stress and qualitative data of care and society open up a discussion about other aspects of illness, broadening our understanding about the relationship between physical status and social surrounding, or what we can refer to as *health*.

### 2.1.3.1. *The bioarchaeology of care*

For as long as there have been humans there have been diseases and injuries. The types and frequencies of pathologies have changed between times, but as a result of these existing pathologies, together with the social and technological abilities of humans, there has also been care. Caregiving at different levels can be seen as part of being human. Because of this, Lorna Tilley developed a way to study care and caregiving in past populations (Tilley, 2015; Tilley and Schrenck, 2017). The idea that care was provided in antiquity has long been under consideration, but care as a part of bioarchaeology has not been accepted and developed for longer than a few years (Tilley and Schrenck, 2017). Tilley means that care is a conscious act that includes both caretakers and caregivers, and that the study of care could therefore tell us something about social relations and societies in the past (Tilley, 2015, p. 1). The question of provided care is therefore interesting to

address when osteological analyses indicate survival for some time with pathologies that would have been disabling in one way or another (Tilley and Schrenck, 2017). The study of care within bioarchaeology is based on skeletal evidence of healed pathological conditions where the suffering individual presumably would not have survived until their present age at death without some sort of care or medical attendance (Tilley, 2015, p. 1).

The bioarchaeology of care is a qualitative study. It is based on meticulous registration of bioarchaeological and archaeological features to create a model of care that must have been provided, given the disability of the care recipient. However, the experience of disability is individually and culturally dependent, which is why disability and care need to be considered in close reference to what is known of the cultural setting in which the individual lived (Tilley, 2015, p. 3). The medical and technological knowledge and skill available in the society must also be considered when assessing a model of care. Recording of archaeological and osteological evidence could be made through the web-based application *Index of Care* (Tilley and Cameron, 2014) where each of the four steps of the index are thoroughly documented and assessed.

There are, of course, limitations to the bioarchaeology of care. First of all, because the necessity of care and the outcome of disability is dependent on many things that cannot be generalized, the bioarchaeology of care is restricted to case studies on an individual level (Tilley, 2015, p. 3). Secondly, there are a number of pathological conditions that do not affect bone, as well as conditions that lead to a quick death and thus do not have time to develop bone alterations. These illnesses are undetectable in bioarchaeological analyses and it is thus impossible to detect all morbidity and caregiving in past societies. As a consequence of this, it is impossible to give a complete and accurate representation of the bioarchaeology of care in ancient societies (Tilley, 2015, p. 3). This means that there are a great number of unrecorded caregivers and recipients of care in prehistory that nonetheless would have had an effect on the society. However, applying the bioarchaeology of care would enable a deepened understanding of illness, disability, care, and society in the past.

The bioarchaeology of care is still a new theoretical and methodological subfield within bioarchaeology, but its development is rapidly moving forward. To date the question of care has been addressed regarding pathological conditions such as leprosy (Roberts, 2017; Matczak and Kozłowski, 2017), trauma (Vlok et al., 2017), paralysis (Schrenk and Martin,

2017), and skull injury/trepanation (Jolly and Kurin, 2017). Jolly and Kurin (2017) also acknowledge the problems in assessing care for individuals with skull trauma since the occurrence of traumatic brain injury is difficult to assess, making the inference of care provided possibly biased. This problem was acknowledged and investigated through an interdisciplinary collaboration between neuropsychology and bioarchaeology in the case of Östra Torp 4 (Tornberg and Jacobsson, 2018) within this thesis.

## 2.2. Osteological background

I have chosen to largely separate the chapter on archaeological background into archaeologies focusing primarily on material culture and archaeologies focusing on bones. This distinction has been made because the scholarly traditions have focused on different kinds of research questions relating to Neolithic and Bronze Age societies. I have also made this distinction to accentuate the need for further research within animal and human osteology in LN–EBA archaeology.

### 2.2.1. Bioarchaeology

Bioarchaeological approaches to the LN–EBA have been scarce, especially where osteology is concerned. In earlier years some osteological analyses of Stone and Bronze Age skeletons were conducted by the anatomist Carl M. Fürst (Fürst, 1911; Fürst, 1914, 1917, 1924). In addition, Gejvall undertook osteological analyses of the skeletal remains from the Dragby gallery grave (Gejvall, 1963), remains which are also analysed in this thesis.

The main focus of bioarchaeology of the south Scandinavian Neolithic and Bronze Age in recent years has been upon stable isotope analysis for dietary reconstruction and mobility (Fornander et al., 2008; Fornander, 2011, 2013; Frei et al., 2015; Blank, 2016; Bergerbrant et al., 2017), as well as ancient DNA (Skoglund et al., 2012; Allentoft et al., 2015; Haak et al., 2015; Malmström et al., 2015). There are only a few osteological studies of Neolithic and Bronze Age southern Scandinavia, almost exclusively based upon MN agro-pastoralists (During, 1989; Ahlström, 2001, 2003, 2009; Fibiger et al., 2013) and foragers (Sjøvold, 1974; Ahlström, 1997, 2011, 2015; Molnar, 2006; Bennike et al., 2007; Molnar et al., 2011).

Osteological analyses of LN–EBA assemblages have mainly been made in relation to excavations as reports or case articles (Lilja, 1994; Edenmo, 2000; Strömberg et al., 2007; Carlie et al., 2014; Brink et al., 2014), but work that approaches syntheses is scarce (Fyllingen, 2003; Fibiger et al., 2013; Tornberg, 2013, 2015; Bergerbrant et al., 2017). However, Pia Bennike’s research (1985), although written 30 years ago, makes a very important synthesis on paleopathology in prehistoric Denmark which is of great value for comparisons. The sparse osteological results based on LN–EBA skeletons in southern Sweden point to high stature and increased rates of dental caries (Tornberg, 2013, 2015). Further, osteological reactions to stress are considerably lower in southernmost Sweden (Tornberg, 2013) than in Denmark (Bennike, 1985), which is also true regarding the presence of violence-related trauma (Fibiger et al., 2013). Repeated violence-related trauma has also been detected in EBA Norway (Fyllingen, 2003). Based on this bioarchaeological data, it seems as if environmental pressure has been higher in Denmark than in Sweden during this period, perhaps due to population density.

Isotope studies on LN–EBA skeletal material from Falbygden, southwestern Sweden, have been conducted by Malou Blank (2016, 2017) and Blank and Knipper (forthcoming). Blank’s research is connected to a doctoral project and will provide very important results regarding the use of gallery graves, mobility, and subsistence in an interesting geographic area. Unfortunately, no studies of dietary reconstructions have yet been published. The Gothenburg University project, “The Rise,” funded by the European Research Council, has further provided interesting results of aDNA, strontium isotopes, and identity studies based on osteological and archaeological analyses of Scanian materials (Bergerbrant et al., 2017). These results point to increased mobility in the later phase of the LN II and the EBA in Falbygden (Blank and Knipper, forthcoming), and a higher relative amount of non-locals found in mounds than were found in flat graves or gallery graves in Scania (Bergerbrant et al., 2017). Within the “The Rise”-project results of aDNA studies, a strong genetic influence similar to that of individuals of the Yamnaya culture of the eastern steppes dating from 3000 BCE onwards was found (Allentoft et al., 2015). This was also almost immediately confirmed by the research of Haak et al. (2015), which gave strong support for the migration theory (Kristiansen, 1989) as the reason for the emergence of the Corded Ware/Battle Axe cultures in the Middle Neolithic B (MNB). It is plausible that these migrators were accustomed to a subsistence focusing on

pastoralism instead of cultivation as among Funnelbeaker populations in the Middle Neolithic A (MNA) (for references see section 2.3.1.).

### **2.2.2. Zooarchaeology**

Strangely, animal bones occur infrequently at LN–EBA sites, and zooarchaeological analyses are therefore scarce and often based on small assemblages. There are a few assemblages from Denmark, but only one quantitatively large assemblage from Sweden, namely Apalle in central Sweden (Vretemark et al., 2010, p. 154), although this assemblage is from the Late Bronze Age (LBA). Unfortunately, I have not found any zooarchaeological assemblage dating to the LN that was larger than a few hundred grams and was thus deemed to be of insufficient quantity to be representative and provide information about subsistence. These materials have therefore not been evaluated further in this thesis.

Animal bone assemblages are predominated by domesticated species. However, in Tanum on the Swedish west coast, the presence of bones of large pollack and cod, together with deep-water fishing equipment, suggest a reliance on marine resources (Vretemark et al., 2010, p. 156). A high level of importance of marine resources in the Bronze Age is further suggested by Berntsson (2005) and bone fish-hooks have been found in Falbygden (Weiler, 1994, p. 61). In the gallery grave at Falköping stad 5, a bone-flute for bird-hunting was also found (Weiler, 1994, p. 61f). The kitchen midden at Sandeplan, Räng parish in Scania, contains a large number of fish bones (Cardell, 1995). A brief osteological analysis made by Hedlund in association to a research project at Lund University in 2010 shows that cattle was the most common domesticate (Hedlund and Nilsson, 2011). However, two things should be considered: i.) Hedlund did not have access to a reference collection during her osteological analysis and because of this, the results should be regarded as highly preliminary. In contrast, the analysis of the fish bones made by Cardell was undertaken with the support reference collection thus making her results of higher validity. ii.) The time frame of this kitchen midden is also long, spanning from the Neolithic Age to at least the LBA. Nine radiocarbon dates of animal bones from Sandeplan were made for this project (Appendix 2) and all dated to the LBA.

Generally, cattle are the most common species in zooarchaeological assemblages from the south Scandinavian Bronze Age (Welinder et al., 2004, p. 103; Vretemark et al., 2010, p. 155). Bone assemblages from the previous

MN agro-pastoral societies also provide evidence of a high reliance on domesticates, but in this period, sheep and/or goats have been predominant followed by pigs (Malmer, 2002, p. 145ff; Sjögren, 2017). This is also the trend of the LBA, where the amount of cattle bones decreases in favour of sheep and, in some cases, pigs (Vretemark et al., 2010, p. 155). Vretemark et al. (2010) further suggest that the age at death distribution in cattle supports an increased level of importance placed upon milk and working oxen, indicative of a subsistence primarily based on animal husbandry and with a high reliance on secondary products. However, the distribution of sheep bones does not support the idea of sheep being kept primarily for wool (Vretemark et al., 2010, p. 155). This is interesting in relation to the results by Frei et al. (2017), who found that 75% of the wool used in Bronze Age textiles in Denmark was of non-local origin. Considering that material culture is very similar between present-day Scania, southernmost Sweden, and present-day Denmark, it is probable that similar subsistence and economy was practiced in both areas. Denmark and Scania are considered core areas in the south Scandinavian Bronze Age, and so it is plausible that more peripheral areas further north differ somewhat in this respect. Considering the low amount of animal bones present from this period, however, this could not be further investigated at present.

### **2.2.3. The bioarchaeology and osteology of the Neolithic. Examples from outside Scandinavia**

Although bioarchaeological research of the Neolithic has been relatively sparse in southern Scandinavia, especially regarding syntheses on Neolithic health, it has been an intense field of research in many parts of the world in the last 30 years or so. The first synthesis on the bioarchaeological effects of the transition to agriculture world-wide was Cohen and Armelagos' anthology (1984). The anthology is the result of a Wenner-Gren-sponsored symposium in 1982 and includes a number of papers exploring skeletal evidence of changes in nutrition and health in relation to the Neolithic transition in different parts of the *Old* and *New World*. The symposium sought to conjoin research on health impacts of the agricultural transition, and to test hypotheses of population pressure and nutritional stress through recent advanced techniques of skeletal analysis (Cohen and Armelagos, 1984, p. xxxvii) The anthology was in line with modern bioarchaeological research with a focus on population health and cultural interpretations, rather than diagnoses of specific pathologies and disease history (Cohen and Armelagos,

1984, p. xxxvii) as has been commonly addressed in previous research. Many scholars reported a decrease in health following the Neolithic transition.

As a celebration of the twentieth anniversary of Cohen and Armelagos' publication, another anthology on ancient health was published in 2007 (Cohen and Crane-Kramer, 2007). During the 20 years in between the publications, a large number of papers from all over the world had further explored the bioarchaeological implications of the transition to agriculture (Cohen and Crane-Kramer, 2007, p. ix). In this 2007 anthology, the editors respond to the critique expressed towards the Cohen and Armelagos publication (Cohen and Crane-Kramer, 2007, p. 3) and manage to include a more geographically spread and thus diverse picture of the health effects of the transition to agriculture, which were based on more standardized measurements and new methods. A general decline in health is also put forward in this volume (Cohen and Crane-Kramer, 2007, p. 342f). However, this picture is more diverse and nuanced than what is evident in the Cohen and Armelagos (1984) publication. This is probably partly due to a more standardized recording procedure, but more so because of larger variety in studied populations and higher inclusion of populations from the *Old World*. A decline in health following the Neolithic transition has also been reported by, for example, Mummert et al. (2011) based on reduced stature, and Papatthanasiou (2005), Larsen (2006) and Wittwer-Backofen and Tomo (2008) based on the frequency of several paleopathological features and stature. Eshed et al. (2010) argue for a complex health profile following the Neolithic transition in the Levant, with an increase in infectious disease, no change in degenerative joint disease, and a decrease in skull trauma among males. Furthermore, in China, a decline in health has been reported within the Neolithic which could be associated with an increase in political-economic differences (Pechenkina et al., 2002).

Much of the focus of the Neolithic transition had so far been on changes in health and paleopathological features. In 2011, a book edited by Pinhasi and Stock was published. In this publication attention is paid to the fact that it is a paradox that there are so many reports of declining health following the Neolithic transition, but that the same transition is so closely related to a demographic expansion and the success of the human species (Pinhasi and Stock, 2011, p. 3). The authors of the publication seek to illuminate different aspects of how the impact of agriculture varies both geographically and chronologically (Pinhasi and Stock, 2011, p. 3). The book is divided into four parts corresponding to bioarchaeological evidence of subsistence transitions,

variations in growth and body size, indicators of habitual activity, and aDNA, paleodemography, and cranial and tooth morphology. Thus, it stretches beyond paleopathology and includes other parameters that reflect health and behaviour that could help explain both positive and negative effects of the transition to agriculture. The authors provide further evidence that the bioarchaeological effects of the transition to agriculture is region specific and that general patterns could not be concluded. This publication has provided important evidence of diet and health following the transition to agriculture.

As Pinhasi and Stock (2011) emphasize, the paradox of declining health and the contradictory success of modern humans as a species following the transition to agriculture needs further research. Lambert (2009) argues that what is favourable in terms of evolution (evolutionary fitness) might not be favourable for health (physical fitness). She demonstrates that there is a close connection between population growth and the transition to agriculture and that despite new ways of living resulting in decreased levels of health in general, these new ways of living did not decrease the reproduction — instead quite the contrary. This argumentation would answer the paradox of the success of modern humans despite simultaneous evidence of declining health.

I believe that further insight into this development can be found by expanding the time period of these investigations to also comprise the MN and LN periods.

### 2.3. The Late Neolithic and Early Bronze Age – A regional archaeological background

The archaeology and timing of the LN and EBA differ between regions. In this thesis I refer to the LN and EBA of southern Scandinavia, more specifically southern Sweden, if nothing else is described. The periods have long been of archaeological interest and studied through different perspectives by archaeologists such as Montelius (1885, 1917), Forssander (1931, 1936), Oldeberg (1974), and Lomborg (1960, 1969, 1973).

Helle Vandkilde defined two phases of the Late Neolithic: the LN I (c. 2350–1950 BCE) and the LN II (c. 1950–1750 BCE), which she based on investigations of early metalwork in Denmark (Vandkilde, 1996). The LN II chronologically corresponds to the classical phase of the Únětice culture, the

first Bronze Age culture in Bohemia. There are traditionally two different burial types connected to the LN: flat burials with single or multiple inhumations, and gallery graves with inhumations of numerous individuals. There is no clear cultural change between the LN and the EBA until around period II (c. 1500 BCE) or perhaps a little earlier, when barrows began to be erected and bronzes became numerous. Holst et al. (2013) estimate that around 50 000 mounds were erected in Denmark in a period of less than 350 years. The burial traditions of flat burials and gallery graves that were present in the LN also expanded into the Bronze Age. In the EBA III, cremations replaced inhumations in barrows. This transition in burial practice is also the end-point of the material included in this thesis.

For the interpretative departure I acknowledge two archaeological themes as central: that of an agro-pastoral intensification and the Secondary Products Revolution (Sherratt, 1981, 2004) in the MNB–LN, and that of the increasing social stratification and a possible warrior elite in the LN–EBA. In this chapter I attempt to give a short overview of current archaeological knowledge about the LN and EBA. The focus will be on interpretations of social formations and agro-pastoral development and does not attempt to be comprehensive.

### **2.3.1. The Late Neolithic and agricultural intensification**

Stensköld proclaims that to understand the LN, it should be put in relation to the rest of the Neolithic rather than the Bronze Age (Stensköld, 2004, p. 20f). Although I partly agree, I believe that it is necessary to put the LN in the context of both the previous and forthcoming periods in order to be able to understand the development during this period. Initially, the LN needs to be related to what is happening in the early third millennium BCE, also known as the Corded Ware culture/Battle Axe culture, but it also needs to be addressed in relation to a fully developed Bronze Age society. There seems to be a cultural change around 2000 BCE, where the part prior to 2000 BCE might be more related to the Battle Axe culture communities and the part after 2000 BCE has more in common with the EBA. This idea is also shared by Iversen (2017). Similar, but not identical, expressions of the Corded Ware culture are present over a large area in central and northern Europe from around 2800 BCE. For southern Scandinavia it is evident that there is a considerable difference in cultural expression between the Funnelbeaker culture (Trichtenbecher Kultur/TRB) in the MNA and the Swedish-

Norwegian Battle Axe culture in the MNB. The people of the Battle Axe culture are associated with single or double graves with strict forms related to gender (Malmer, 1962) instead of collective burials in passage graves, as was practiced among the Funnelbeaker culture. It has been debated whether the Battle Axe culture was the result of domestic, local or regional, development of the earlier Funnelbeaker culture (Malmer, 1962; Damm, 1991; Fokkens, 1998) or whether it was spread through migrations (Kristiansen, 1989; Anthony, 2007). Evidence from ancient DNA studies supports the migration theory, with a genetic influx from, what is interpreted as, individuals belonging to the Yamnaya culture (Haak et al., 2015; Allentoft et al., 2015) who also had similar cultural expressions as the Corded Ware culture (Kristiansen, 1989, p. 215; Anthony, 2007, p. 367). These migrators are also thought to have brought the domesticated horse which could have played an important role in cattle and sheep pastoralism (Anthony and Brown, 2011). Although these studies contribute to new, valuable information about the past, I would like to raise caution concerning the equation of genes and culture. Genes do not automatically carry culture; similarly, culture does not automatically carry genes. However, it is more likely that people within the same or a similar group meet and mate since it is more probable that these individuals understand each other culturally and linguistically; generally, you want to understand the person you mate with. Individuals that live close together are also more likely to have similar genes considering that they have probably been interbreeding for a longer time period, at least in pre-globalized time periods. In this respect, there might be a connection between shared culture and shared genes. The relationship between genes and culture is also discussed by Heyd (2017). Heyd emphasizes that the results from aDNA might not reflect single events of migrations in one direction, but rather reflect centuries of contact between populations over large areas of Eurasia (Heyd, 2017).

In contrast to the Funnelbeaker culture in the MNA, evidence of permanent settlements from the MNB, Swedish-Norwegian Battle Axe culture, is generally lacking in terms of archaeological material in the early phase, and does not appear until the transition to the LN in southern Sweden, which is interpreted as indicative of people of the Battle Axe culture being nomadic pastoralists (Larsson, 1992; Andersson, 2003, p. 260). Malmer et al. (1986), however, interpreted this phenomenon as Battle Axe culture settlements being situated in heavily utilized agricultural areas which were then destroyed in modern times. It is possible that the scarce evidence of permanent settlements in the initial part of the Battle Axe culture is in part

due to taphonomic reasons. However, it has been put forward that the emergence of farms and the abandonment of palisade enclosures at this time instead indicate a shift in focus on where to gather for social events (Brink, 2009, p. 349). The large excavation areas that are often the case within contract archaeology are well suited for finding settlements, but the amount of Battle Axe culture houses still remains low (Andersson, 2003). It is probable that the differences in settlement frequencies are, in fact, expressions of a development towards more settled and intense agro-pastoral subsistence and increased social stratigraphy. Pollen diagrams provide evidence for a distinct increase in forest clearance and pasture lands first around the MNB and later, and, most profoundly, in the EBA (Digerfeldt, 1975; Berglund, 2003; Engelmark and Linderholm, 2008). The shaft-hole axe of the LN is probably also connected to this forest clearance. New areas were populated during the LN and are considered to be associated with a population increase (Apel, 2001, p. 11; Apel and Knutsson, 2004) and a probable need for growing stocks to graze. An increase in cultivated lands is also evident through the finds of numerous pressure-flaked flint sickles, some with evidence of gloss (Iversen, 2017, p. 367).

Large houses and farm estates with several houses appear around 2000 BCE. They are interpreted as inhabited by the social elite (Artursson, 2005; Kristiansen, 2006; Brink, 2009, p. 351). Artursson provides evidence of a culmination of house size in the EBA and the relative size difference between the smallest house and the largest house is also bigger in the EBA than during the LN. This is a trend that increases from the LN I and is interpreted as a likewise increase in social stratification (Artursson, 2009, p. 204 ff). The burial tradition of the LN is somewhat complicated, with both single graves and graves with multiple inhumations present. Flat burials, with a single or with multiple inhumations, co-exist with inhumations and megalithic gallery graves and reburials in MN megaliths. However, the burial tradition differs somewhat between regions. While flat burials are quite common in Scania during the LN, they have not been found in Västergötland in southwestern Sweden. However, three inhumed individuals found in a shell midden with associated flint daggers in Sillvik, Torslanda parish in Gothenburg in western Sweden, might have been given a flat burial similar to those in Scania (Sjögren et al., 2009). This indicates that there might be more flat burials in southwestern Sweden, but it is unlikely that they exist in the same frequency as in Scania. Burial goods also differ between the burial traditions, and gallery graves generally contain fewer burial goods per capita than what is commonly found in flat burials (Stensköld, 2004, p. 136). Apel argues that a

hierarchical society is already present in southern Scandinavia during the LN (Apel, 2001). He addresses the question through analyses of flint dagger production and distribution and argues that learning the craft of flint dagger production is so time consuming and demanding of skill that the daggers must have been produced by specialists. He implies that this specialization was upheld by a hereditary hierarchical system indicative of a chiefdom-like community. Further, flint daggers were distributed through direct exchange into areas where flint was not naturally present, which required redistribution centres both locally and regionally. Instead of an increased importance of the collective during the LN in relation to the preceding “individualistic” Battle Axe culture, a socially stratified society seems to have been present already at the onset of the Bronze Age.

### *2.3.1.1. The Secondary Products Revolution*

An increased pastoral economy is closely related to the utilization of secondary products. The idea of the Secondary Products Revolution, or the shift in focus from cultivation and domestic meat consumption towards the use of animal secondary products, such as milk and using animals for traction, was first introduced by Andrew Sherratt (1981). The Secondary Products Revolution is not considered to be one single event but is dated differently according to both the geographic region and the specific secondary product in question (Sherratt, 2004; Marciniak, 2011). The use of milk, for instance, is probably dated earlier than the use of the cart, and the Secondary Products Revolution has an earlier dating in the area around the Fertile Crescent than in southern Scandinavia. Despite initially receiving some criticism, the Secondary Products Revolution model has been supported by further findings. Zooarchaeological remains generally support a shift from meat farming and consumption towards milk and wool production in the Chalcolithic (Greenfield, 2010). A misunderstanding of Sherratt’s model is that the first-time appearance of secondary products is referred (Greenfield, 2010). Recent studies of lipids show that milk was already being utilized in the Swedish EN (Isaksson and Hallgren, 2012; Lindboe, 2014), although it is unknown to what extent, since the genetic ability to digest milk sugar is low (Burger et al., 2007; Malmström et al., 2010; Allentoft et al., 2015). However, Sherratt argues that it is the shift in focus, not the initial appearance, that he refers to as the Secondary Products Revolution (Sherratt, 2004). Heavy reliance on secondary products in the initial phase would not have been possible since many of the traits necessary for secondary products, such as a well-developed undercoat in sheep and continuous milk production

in cattle, are selected for after domestication and are not present in their non-domestic counterparts.

The increased utilization of milk resulted in storable dairy products that improved the amount of nutrition for humans without the need to slaughter the animals. Further, the domestication of the horse opened up the possibility of trade over longer distances while the use of primitive ploughs and manuring enabled cultivation in earlier non-profitable land. The use of primitive ploughs could quadruple the output for the farmer (Sherratt, 1981, p. 287). The development of wool from sheep also allowed for making new kinds of textiles.

Sherratt explained the development towards a shift in focus as the result of population pressure, where the need to expand into peripheral (with less fertile soils) areas called for new sources of nutrition and new innovations (Sherratt, 1981, p. 286). The exploitation of secondary products made pastoralism favourable and growing stocks could graze in areas where plant cultivation was not possible (Sherratt, 1981). Sherratt further puts the Secondary Products Revolution in close connection with the rise of complex societies (Sherratt, 1997; Greenfield, 2010, p. 31). The Secondary Products Revolution resulted in increased levels of nutrition and more arable land which allowed for further population increase but also generated food surplus which could be traded. All of the above are considered to be triggers for the development of Bronze Age societies (Earle, 1989). An increased amount of storables would also have some evidence in the archaeological record. Sherratt argues that there is a radical shift in pottery styles in the Bronze Age to include drinking and pouring vessels, which would result from the increased use of milk and dairy products in this period (Sherratt, 1981, p. 280). Hulthén also argues that although not visually as beautiful as pottery from the MN, the LN pottery was not poor in quality—rather the opposite. Hulthén suggests that pottery went from being a prestige item associated with graves and ritual and developed into vessels suitable for every-day use, such as for storage and food preparation, e.g. for making beer (Hulthén, 2013). As presented above, Isaksson and Hallgren (2012) found traces of milk lipids in ceramics dating to the EN Funnelbeaker culture in central Sweden. Further, Craig et al. found a small amount of fats probably deriving from bovine milk in EN pottery sherds from central and eastern Europe (Craig et al., 2005a) and large amounts of fats from bovine milk in Scottish pottery sherds from the LBA–Early Iron Age (Craig et al., 2005b). These pieces of evidence support the idea of an increased reliance on secondary products in the late

part of the Neolithic or in the early part of the Bronze Age. Direct evidence of milk consumption has been detected in dental calculus from individuals dating to the Bronze Age in Europe (Warinner et al., 2014) and in MN and LN individuals from Falbygden, southwestern Sweden (Fotakis et al., forthcoming). In addition to this there is a stone-paved road with clear wheel tracks in the area around Malmö in southernmost Sweden that have been radiocarbon dated to 1050–790 cal BCE (2 sigma) (Winkler, 2004). These pieces of evidence are thus consistent with Sherratt's idea of the Secondary Products Revolution in the fourth–third millennium BCE. Social inequalities and economically based hierarchies emerge in contexts where continuous production of resource surplus is available (Hayden, 1995, p. 21). This makes it highly interesting to evaluate bioarchaeological responses to nutrition and health, and the relationship between an assumed socially stratified society in the Bronze Age and a probable intensification of agricultural practice and the Secondary Products Revolution in the MN–LN.

### **2.3.2. The Early Bronze Age – Warrior elites and social stratification?**

Most scholars today are unanimous in their opinion that the Bronze Age is built upon a hierarchical society. Some scholars understand this process to have already begun in the LN (see above, section 2.3.1.) while others relate this development to the distribution of metal, and therefore place the process in the EBA Ib or EBA II (Vandkilde, 1996; Kristiansen, 1999; Earle, 2002; Kristiansen and Earle, 2015). The building of numerous barrows in the EBA is a still-visible expression of the elite burials. Holst et al. (2013) estimated that approximately 20% of the Bronze Age individuals have been buried in barrows. The burials of the commoners have long remained undetected. Recent investigations of numerous radiocarbon dates from Scania within the “The Rise” project suggest an intense use of gallery graves in the EBA, interpreted as the burial of commoners (Bergerbrant et al., 2017).

Trading was a very important part of Bronze Age society and long-distance trade was established and upheld by a political elite (Vandkilde, 1996; Harding, 2013; Earle et al., 2015; Kristiansen and Earle, 2015). Considering the vast number of finds of weaponry in graves and hoards, as well as depicted battles, there is strong evidence that this elite should be interpreted as a warrior elite (Harding, 1999; Kristiansen, 1999; Fyllingen, 2003). Iversen (2017) argues that warrior elites that were later fully established in

the EBA were introduced already in the MNB Corded Ware cultures. Copper and tin, as well as gold and silver, were traded over large parts of Europe (Earle et al., 2015). Frei et al. (2017) show that the long-distance trade of wool was also practiced to a large extent, with non-local wool being found in 75% of analysed textiles, more commonly in graves with indicators of high status. The number of individuals with a non-local  $^{87/86}\text{Sr}$  signature is markedly higher in the EBA than in the LN (Bergerbrant et al., 2017) and the number of non-locals is higher in high-status graves (Frei et al., 2015; Bergerbrant et al., 2017), indicating a general increased mobility that is highest among the elite. For a further introduction to strontium isotope methodology, I recommend section 4.2.3.

Trade was intensely connected to political power and Bronze Age societies are thought to have been highly interconnected economically and socially (Harding, 2013). Much of Bronze Age research has been interpreted through the goggles of World Systems Theory, where centre and periphery areas are closely intertwined and the core areas influence the periphery, both socially and economically (Kristiansen and Larsson, 2005; Kristiansen and Earle, 2015). This approach is partially opposed by Harding (2013) who, although agreeing with the centre-periphery hypothesis, promotes a local view where there are a number of core areas with their own peripheries throughout Europe. Skoglund (2009) argues that the strategies for upholding power were different within southern Scandinavia, where corporate strategies associated with Neolithic societies remained in the peripheries, while network strategies, where power was upheld through prestige items of the elite, were practiced in the core areas. This situation would support Harding's theory. Skoglund discusses Denmark and Scania as core areas in southern Scandinavia, while Västergötland and Bohuslän in southwestern Sweden should be regarded as more peripheral. This centre-periphery is visible, for example, through the monumental grave form present in southernmost Sweden while lacking in the southwest (Skoglund, 2009). Kristiansen and Earle, however, insist that the big difference between Neolithic and Bronze Age societies lies within the scale of economy, where Neolithic societies are based exclusively on local resources while Bronze Age political exchange were large scale and over long distances (Kristiansen and Earle, 2015).

# 3. Material

The material in this thesis is a collection of bones from 46 localities in southern Sweden. The localities are situated in three sub-areas; southcentral Sweden, southwestern Sweden and Scania in southernmost Sweden. Skeletons from single graves and multiple inhumations in gallery graves were included in the Scanian sample, but only gallery graves were included from the other sub-areas. Only unburned bones were selected, even though there is also evidence of cremations (Hansen, 1937; Olausson, 2015). Cremated skeletal remains seldom provide information other than the number of individuals and possibly their ages and sexes. However, strontium isotope studies for mobility analyses have proven successful on cremated bones too (Harvig et al., 2014). There are examples where paleopathological features could be detected (Charlier et al., 2014), but this is not very common. Since this information is way too scarce to build a discussion about health upon, all cremated remains were discarded. In addition to the skeletal remains, this thesis is also built upon reports, excavation documentation, and biochemistry.

## 3.1. Selection and representivity

All available material from Scania which it was possible to analyse, considering the accessibility in museums, available archaeological documentation, and preservation, was included. Skeletal material that had possibly commingled with other skeletal samples, as well as skeletal remains that were very poorly preserved, have been excluded from analysis. The focus is on Scanian material because of my own familiarity with the skeletal material (Tornberg, 2010, 2013) and the archaeological context. Further, there is a large quantity of skeletal material available, due to both good preservation and a beneficial archaeological tradition, providing a good bulk sample. The counties of Västergötland, Östergötland, and Närke were chosen due to good, or relatively good, sample sizes in museum collections. One locality from the province of Uppland was chosen because of its northern

boundary and its good documentation as well as good preservation. The materials were later selected due to their bulk and their degree of preservation. Very poorly preserved remains were discarded initially since they could not provide answers to the target questions of my research. The areas of investigation are also highly interesting archaeologically considering the seemingly high population density during prehistory. The county of Småland also appears to have had a large population during the LN, as evidenced by the documentation of hundreds of gallery graves (Ryberg, 2008). Unfortunately, the soil is not favourable for bone preservation.

It is, however, of importance to consider that the majority of the skeletons derive from excavations in the early twentieth century. Some of the excavations even date back to the late nineteenth century. This means that no modern techniques for documentation have been available, and most reports are written by hand with only a few drawings and a few photos attached to them. It is possible that modern excavation techniques would have allowed further analysis of the spatial orientation of the skeletal remains and that the bones would not have appeared as commingled. Even though these problems exist, the early dates of excavation have provided skeletal material which is very well preserved—seldom the case in recently excavated burials. This is probably due to acidic rain and other environmental effects in combination with modern agricultural machinery (Swedish National Heritage Board, 2014).

A minimum number of 310 individuals were included in this study, of which 84 individuals were juveniles and the remaining 226 individuals were adults of different ages. Of these individuals, 60 adults and 78 juveniles could be aged more specifically. With the exception of one, all individuals had been typologically dated to the LN–EBA. The last individual, a single individual from Östra Torp 4 in southernmost Sweden, was thought to be associated with the Swedish-Norwegian Battle Axe culture in the MNB. This was later confirmed by radiocarbon dating.

Since the materials are very different in character, both due to burial practice and preservation, not all materials have been examined in all studies. The different sites are presented briefly in this chapter, sorted by province. Since the number of localities from Scania is abundant, only a few key sites will be presented in more detail, while the rest of the material is presented in bulk. Although the 313 individuals included in this study add up to only a minority of the population once living in southern Sweden in the LN and EBA, this

thesis offers the most comprehensive data from Neolithic–Bronze Age Sweden so far.

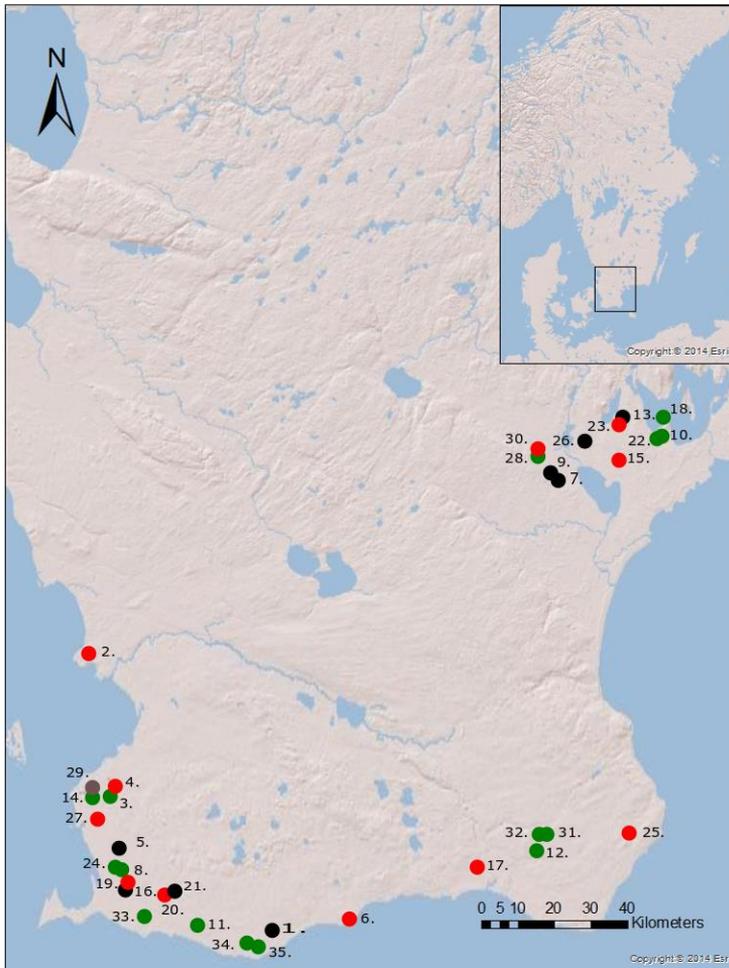
## 3.2. The Scanian Late Neolithic and Early Bronze Age burials

The foundation of this thesis lies in the skeletal material from Scania, southernmost Sweden (Figure 1). The province of Scania is represented with the largest assemblage deriving from 37 localities (Table I).

The sites are mostly coastal or in close vicinity to a coastal region. Whether this is due to actual prehistoric settlement patterns, an effect of modern excavation distributions, or differences in preservation conditions, it is difficult to say, but it is possible that the explanation is a mixture of all of the above. I would like to stress that most of the Scanian material has an early excavation date, primarily before 1950, therefore documentation, such as photos, plans, and reports, are scarce and often of poor quality, and are sometimes missing altogether. Due to the effects of acidic rain and modern ploughs the more recently excavated skeletons were in a poor condition and could rarely be investigated in relation to the research questions at hand. Because of reported or documented poor preservation, the LN skeletal remains from Gyllin's garden in the Malmö area (Carlie, 2007) and Herrestorp outside Vellinge (Brink et al., 2014) were excluded from analysis. During the early summer of 2017, LN burials, some with relatively well-preserved skeletons, were found outside Hjärup in the vicinity of Lund during an excavation made by the National Historical Museum: The Archaeologists. Unfortunately, these remains could not be included in the analysis since their excavation was undertaken too late in the work process of this thesis.

Scania displays heterogeneous burial traditions during the LN and EBA. There are only a few examples of cremations, none of which are integrated into this research, but the inhumation traditions during this period vary between flat single graves, flat graves with multiple inhumations (often two), reburials in MN passage graves, single inhumations in collective burial mounds, and collective burials in gallery graves. All of these traditions are represented in this thesis. A large number of radiocarbon dates have been necessary to be able to interpret the material, as well as to distinguish possible secondary burials from later times, and to establish LN–EBA burials

from MN burials in a re-used passage grave in Öllsjö 7. Associated radiocarbon dates are presented in connection to each locality in the material section. The complete sample of radiocarbon dates is presented in Appendix 2.



**Figure 1.**

Scanian localities included in this thesis. Map created using ArcGIS 10.5 by Esri. Red= barrows, green= flat burials, black= gallery graves, and gray= unknown. 1=Äspö, 2= Rörbäck 10, 3= Tannhäuser, 4= Höjagården, 5= Vattenöverföringsledningen, 6= Abbekås (barrow I & II), 7= Ängamöllan, 8= Kjylbjersbacken, 9= Öllsjö 7, 10= Kiaby 80, 11= V. Virestad 19, 12= Bollerup 4, 13= Österslöv 57, 14= Järavallen, 15= Riksvägen, 16= Häslöv 5, 17= Hemmanet, 18= Bäckaskogs kungsgård, 19= Åkes hög, 20= Hammarlöv 6, 21= Bonhög, 22= Kiaby mosse, 23= Österslöv 24, 24= Vellinge 27, 25= Viarp, 26= Möllebacken, 27= Solnäs, 28= Skepparslöv, 29= Knuts backe, 30= Skepparslöv 20, 31= Hammenhög 26, 32= Hammenhög 35, 33= Ahlbäcksbacken, 34= Snorthög, 35= Östra Torp 4.

The Scanian material is well preserved but is, however, heavily affected by differences in burial practice. Since part of the material derives from single inhumations in flat graves or mounds/cairns while another part derives from severely commingled remains from gallery graves containing a large number of individuals, it has been necessary to carry out different approaches on the different kinds of material. Mostly, the number of affected specimens have been applied when analysing the material in terms of pathological changes, rather than the number of individuals per se. However, the single burials give invaluable insights into the diet and health on an individual plane.

Due to the large number of localities from Scania, a complete list of materials and localities is presented in Appendix 1 in the form of summary tables. However, five Scanian sites have been further presented below. These sites have been selected because they are well documented and include a rather large number of skeletons. They also represent all burial types associated to the LN and EBA in the area.

**Table I.**

The Scanian material included in this thesis. GG=gallery grave; C=cairn; F=flat burial; B=Barrow.

Locality	Parish	Raä no.	Inventory	MNI ad	MNI juv	MNI tot.	Grave type
Äspö 16	Äspö	n.a.	LUHM 26981	4	0	4	GG
Rörbäck 10	Barsebäck	Barsebäck 10:1	LUHM 26967	3	0	3	C
Tannhäuser	Fosie	Fosie 15:1	MHM 1247 1247	1	0	1	F
Höjagården	Malmö	Västra Skrävlinge 3:1	MHM 1264	1	1	2	B
Vattenöverföringsledningen Hyllie, Vellinge	Hököpinge	Hököpinge 34	MHM 265	1	0	1	F
Abbekås, hög 1	Skivarp	Skivarp 19:1; 19:2	LUHM 20797	11	2	13	F/GG/B
Abbekås, hög 2	Skivarp	Skivarp 20	LUHM 20918	2	3	5	B
Vä, Ängamöllan	Vä	Vä 31:1	LUHM 28771	13	2	15	GG
Kyhlbjersbacken	Vellinge	Vellinge 5:1	LUHM 27499	4	5	9	F
Öllsjö 7	Skepparslövs	Skepparslövs 81:1	LUHM 28775	6	2	8	GG
Kiaby 80:1	Kiaby	Kiaby 80:1	LUHM 28916	3	1	4	F
V. Virestad 19	Västra Virestad	Västra Virestad 19	LUHM 18577	4	2	6	F
Bollerup 4	Bollerup	Bollerup 4:1	LUHM 28204	0	1	1	F
Österslöv 57:1	Österslöv	Österslöv 57:1	LUHM 26810	2	0	2	GG
Järavallen	Hyllie	n.a.	LUHM 17024	1	0	1	F
Gustav Adolf, Riksvägen	Gustav Adolf	n.a.	SHM 22059	1	2	3	B
Håslöv 5	Håslöv	n.a.	SHM 22250	11	1	12	GG
Hemmanet nr 15	Stora Köpinge	n.a.	SHM 5654	6	1	7	B
Bäckaskogs kungsgård	Kiaby	Kiaby 37:1	SHM 21544	2	0	2	C
Norra Håslöv, Åkes hög	Håslöv	Håslöv 1:1	SHM 10288	2	2	4	B
Hammarlöv nr 6	Hammarlöv	n.a.	SHM 8742	1	0	1	B

<b>Hammarlöv by 19; Bonhög</b>	Hammarlöv	Hammarlöv 4:1	SHM 9169	1	0	1	GG
<b>Kiaby mosse</b>	Kiaby	Kiaby 24:1	SHM 15779	1	1	2	F
<b>Österslöv 24</b>	Österslöv	Österslöv 137:2	SHM 4125	2	1	3	B
<b>Vellinge 27</b>	Vellinge	Vellinge 11:1	SHM 13937	2	2	4	F
<b>Kyhlbjersbacken</b>	Vellinge	Vellinge 5:1	SHM 20598	1	1	2	F
<b>Viarp</b>	Simris	Simris 2:1	SHM 7731	0	1	1	B
<b>Möllebacken</b>	Nosaby	Nosaby 18:1	SHM 6906	16	5	21	GG
<b>Solnäs 10</b>	Västra Klagstorp	n.a.	LUHM 25568	2	1	3	B
<b>Skepparslöv</b>	Skepparslöv	n.a.	LUHM 20804	0	1	1	F
<b>Knuts backe</b>	Hyllie	n.a.	LUHM 17042	1	0	1	n.a.
<b>Skepparslöv 20</b>	Skepparslöv	Skepparslöv 18:1	LUHM 28784	0	1	1	B
<b>Hammenhög 26</b>	Hammenhög	n.a.	LUHM	2	1	3	F
<b>Hammenhög 35</b>	Hammenhög	n.a.	LUHM 32824	6	1	7	F
<b>Albäcksbacken</b>	Maglarp	Maglarp 23:1	LUHM	2	0	2	F
<b>Snorthög</b>	Lilla Isie	Lilla Isie 23:1	LUHM 28424	10	1	11	F
<b>Östra Torp 4</b>	Östra Torp	Östra Torp 25:1	LUHM 28423	1	0	1	F

### 3.2.1. Two barrows in Abbekås, Skivarps parish

In the years 1920–1923, three Bronze Age barrows were excavated in the small fishing village of Abbekås outside of Trelleborg in southernmost Scania. The excavation was led by the archaeologist Folke Hansen, curator at the Lund University Historical Museum (LUHM). Barrow I (inventory number LUHM 20797) contained several inhumations while Barrow II (LUHM 20918) contained both inhumations and cremations. The inhumations from these graves were included in this thesis. Like the second barrow, the third (LUHM 20919) contained both inhumations and

cremations. However, the skeletal material was so poorly preserved that it could not be analysed and was therefore not included in this thesis. The results have been published by Hansen (1924), and were later further analysed by Olausson (1993), Bergerbrant (2007), Tornberg (2013), and Bergerbrant (2014).

### 3.2.1.1. Barrow I

Barrow I had a diameter of 14m ×13m and was only one metre high. The filling consisted of cobblestones and gravel which was covered by soil. The barrow contained 15 graves from the LN and EBA, both underneath and within the barrow. Both males and females were buried, but only two juveniles. In total, 13 individuals could be osteologically examined for this thesis. Two graves had multiple inhumations: a gallery grave and one grave right outside the eastern wall of the gallery grave. The gallery grave had been disturbed during the 1880s and human bones and a bronze dagger were found. The bones were only partly restored and the dagger was unfortunately sold (Hansen, 1924). Nine individuals from Barrow I have been radiocarbon dated within this project. The oldest grave (grave I) underneath the barrow has been dated to 2275–1945 cal BCE (LuS 10618), equalling the LN I, and the youngest grave (grave 15) was dated to 1451–1271 cal BCE (UBA-22838) equalling the EBA II–III. All dates are presented in Table II. The individual in grave 15 was found with a 62 mm ×56 mm ante mortem penetration to the left parietal (Figure 2), interpreted as a trepanation (Hansen, 1924; Fürst, 1924; Tornberg, 2013).

**Table II.**

Radiocarbon dates from Abbekås Barrow I conducted within this project.

Grave/Individual	Burial Type	<sup>14</sup> C date BP	<sup>14</sup> C Date (cal.) BCE	Lab no.
1	Flat	3700 ± 50	2275–1945	LuS 10618
4:1	Gallery grave	3600 ± 50	2134–1777	LuS 10619
4:2	Gallery grave	3585 ± 50	2125–1772	LuS 10620
5:1	Flat?	3453 ± 35	1883–1686	UBA-22837
5:3	Flat?	3387 ± 38	1866–1561	UBA-22840
11	Mound	3197 ± 21	1504–1428	UBA-22836
14	Mound	3144 ± 49	1509–1281	UBA-22835
7	Mound	3131 ± 33	1496–1298	UBA-22841
15	Mound	3111 ± 35	1451–1271	UBA-22838



**Figure 2.** The individual in grave 15 in Abbekås, Barrow I, with a 6 mm 2 × 56 mm ante mortem penetration to the left parietal. Photo: Anna Tornberg.

### *3.2.1.2. Barrow II*

Barrow II had the same diameter as Barrow I (14m ×13m) but was considerably higher (1.75m). The majority of the barrow was made up of fine sand, but parts of it also consisted of gravel and cobblestones (Hansen, 1924, p. 35f). In total, ten graves were found in Barrow II, of which five individuals were children. Three of the children's graves (graves 2, 3, 4) also contained copper and bronze artefacts in the form of a diadem and arm and finger rings (Hansen, 1924, p. 37). Unfortunately, only two adults and three children could be osteologically analysed for this thesis since the rest of the material was too fragmentary or missing completely in some cases. Only one individual from the bottom of the barrow (grave 7) was radiocarbon dated to 1865–1627 cal BCE (UBA-22992), i.e. the transition LN II–EBA I. This

dating is consistent with the typological dating of grave 2 where Bergerbrant (2007) interprets the diadem to be of the same kind as diadems found on the European continent until around 1600 BCE, i.e. south Scandinavian period I.

### 3.2.2. Lilla Isie 23, Snorthög

The site of Snorthög is a barrow that includes LBA cremations with LN flat burials underneath. The site was excavated by Bror-Magnus Vifot in 1938 after a removal of the barrow was requested by the people living in the vicinity since it obscured the sight when travelling on the road. The barrow was approximately 21m in diameter and 2m high.

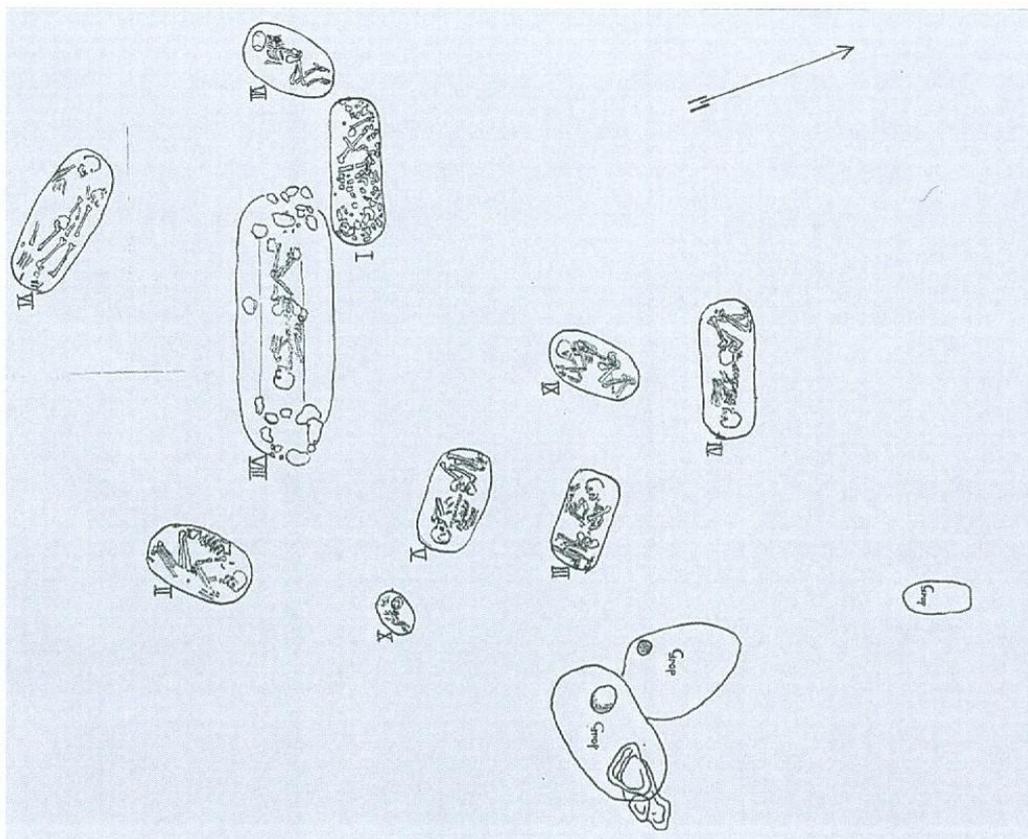
The Bronze Age cremations were found inside the barrow while the ten flat burials were found underneath the southern part (Figure 3). The burials were visible as dark-coloured oval or rectangular areas and only one of them (grave I) was covered with a small cairn. Grave X was an infant burial. Beside the skeleton was a small cup in loosely burnt clay. Other artefacts in the graves included a few pieces of pottery sherds (grave VI), two flint daggers (graves IV and VII), a flint arrowhead (grave II), half of a granite whetter (grave I), and a flint arrow head and a flint scraper (grave V). Graves III and IX also included remnants of wood.

Five individuals were radiocarbon dated within this project, with four graves being dated to the LN I and one grave to the LN II (Table III). The barrow was moved 20 m to the north in association to the excavation.

**Table III.**

Radiocarbon dates from Lilla Isie, Snorthög, conducted within this project.

Grave/Individual	Burial Type	<sup>14</sup> C date BP	<sup>14</sup> C Date (cal.) BCE	Lab no.
V	Flat	3726 ± 35	2275–2025	UBA-22851
VIII	Flat	3694 ± 32	2198–1977	UBA-22852
II	Flat	3616 ± 41	2132–1884	UBA-22850
IV	Flat	3608 ± 32	2113–1887	UBA-22849
IX	Flat	3571 ± 32	2024–1780	UBA-22853



**Figure 3.**

Drawing of the burial site of Snorthög, Lilla Isie parish from the excavation documentation (LUHM 28424). Several individuals were buried in a crouching position which resembles the burial tradition of the Swedish-Norwegian Battle Axe culture. Published in courtesy of LUHM.

### 3.2.3. Kjyhbjersbacken in Vellinge

The site of Kjyhbjersbacken in Vellinge parish was excavated during 1934–1935 by archaeologist Folke Hansen at the Lund University Historical Museum after farmers had partly destroyed several prehistoric graves when digging for gravel (Figure 4).

About ten different graves, with both single and multiple inhumations, were found (ATA dnr. 2285, 2252). Hansen further excavated one grave in 1944 after finds of human bones were reported in association with continued gravel

digging on site (ATA dnr. 0888). The site is located on a ridge once 40–50m long and oriented north-south. The graves were all considered to be Late Stone Age or EBA (ATA dnr. 2285, 2252). 11 skeletons from Kjihlbjersbacken could be analysed for this thesis (Figure 5). The material is divided between museums, with some skeletons in the care of the Swedish History Museum (SHM) and the majority at Lund University Historical Museum. A total of seven radiocarbon dates were conducted within this project, spanning from the LN I to EBA II (Table IV).



**Figure 4.**

The site of Kjihlbjersbacken, partly destroyed after digging for gravel. Photo: Folke Hansen (ATA 2285/1934:1).



**Figure 5.**  
Grave 6 at Kyhlbjersbacken, dated to the LN I. Photo: Folke Hansen (ATA 2285/1934:9).

**Table IV.**  
Radiocarbon dates from Kijhlbjersbacken conducted within this project.

Grave/Individual	Burial Type	<sup>14</sup> C date BP	<sup>14</sup> C Date (cal.) BCE	Lab no.
9	Flat	3805 ± 53	2460–2056	UBA-24002
6	Flat	3715 ± 50	2196–1981	LuS 10621
6	Flat	3697 ± 28	2196–1981	UBA-24000
8	Flat	3675 ± 50	2201–1925	LuS 10622
A	Flat	3675 ± 40	2145–1940	LuS 11853
15	Flat	3537 ± 28	1946–1771	UBA-24003
12	Flat	3073 ± 28	1414–1263	UBA-24001

### 3.2.4. Vä, Ängamöllan

The gallery grave at Vä, Ängamöllan, was excavated in 1945 by archaeologist Holger Arbman and his assistant Berta Stjernqvist. The grave was situated approximately 300m from the manor Ängamöllan and around one kilometre northeast of Vä church. The gallery grave was oriented east-west and the stone slabs were visible approximately 25cm above the ground before the excavation. The grave measured 3.6m by 1.5–1.7m. There was no evidence of roof slabs and there was no gable in the east. It is possible that the grave had been covered by a stone packing instead. The bottom of the grave in the east and west was paved with stone slabs (Magnusson, 1947, p. 137ff). Three skeletons were undisturbed while other bones were partly articulated and others completely commingled. It is evident that older burials were swept aside to make room for new inhumations. At least 14 individuals were interpreted to have been buried in the gallery grave (Magnusson, 1947, p. 140). The grave goods could not be assessed to individuals, with the possible exception of a dagger and a bone pin found in the bottom layer, but comprised three flint daggers, a spear head of flint, three pins and a bone awl, fragmentary ceramics, two flint scrapers, slightly worked chips of flint, and a flint blade (Magnusson, 1947, p. 140). During the osteological analysis for this thesis a minimum number of 15 individuals—13 adults and two children—were documented. Four radiocarbon dates were conducted for this thesis (Table V).

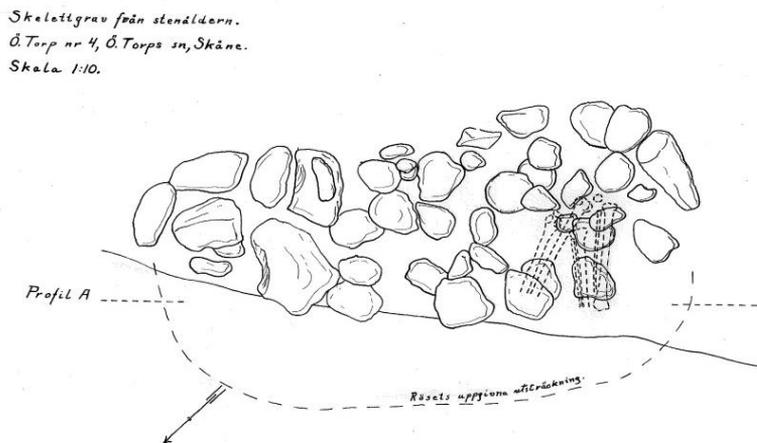
**Table V.**  
Radiocarbon dates of Vä, Ängamöllan conducted within this project.

Grave/Individual	Burial Type	<sup>14</sup> C date BP	<sup>14</sup> C Date (cal.) BCE	Lab no.
VIII	Gallery grave	3105 ± 29	1433–1289	UBA-23998
A	Gallery grave	3070 ± 29	1415–1260	UBA-23997
XI	Gallery grave	3025 ± 34	1396–1131	UBA-23999
III	Gallery grave	3004 ± 40	1392–1117	UBA-23996

### 3.2.5. Östra Torp 4

The grave in Östra Torp no. 4, between the towns of Trelleborg and Ystad, was excavated by the archaeologist Bror-Magnus Vifot in June 1939 after it had been found and reported by the farmer living there. The grave was partly destroyed when Vifot arrived but was approximately 2.2m long and covered by a cairn. Only the lower limbs were found in situ. The rest of the skeleton was mixed in the crumbled gravel that once formed the grave filling, together with a hole-edged flint axe, three flint blades, and some coarse and thick pottery sherds. The bones in situ suggest a crouching position in the grave (Figure 6).

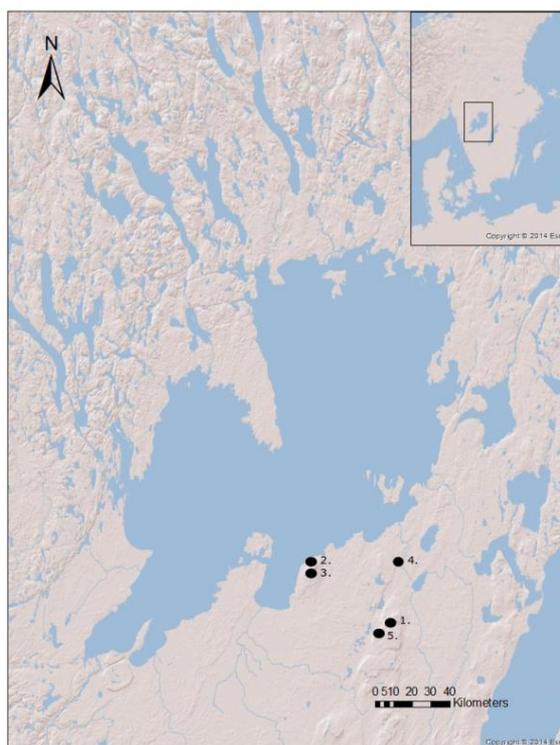
The burial is dated to the MNB and associated with the Swedish-Norwegian Battle Axe culture. A radiocarbon date of 2475–2334 cal BCE (1 sigma, UBA-30562) dates the burial to the late part of the MNB. The buried individual is a male aged 45–90 years, probably towards the lower value, who had suffered from severe blunt force trauma to the head months or years prior to death. The buried individual is the oldest skeleton included in this thesis and the only skeleton that is not dated to the LN or EBA. This individual is only included in Paper V.



**Figure 6.** Drawing of the grave at Östra Torp 4 from the excavation documentation (LUHM 28423). The gravel had crumbled and left only the lower legs in situ when the archaeologist Bror-Magnus Vifot arrived. Published in courtesy of LUHM.

### 3.3. Five gallery graves of Västergötland, southwest Sweden

The Neolithic landscape of Västergötland is magnificent. The area of Falbygden is famous for the numerous MN passage graves, well still characterizing the landscape. There seems to have been a large population in Västergötland by the MN according to the large amount of passage graves in the area. The degree of preservation of bones is varying, largely depending on locality. Because of the archaeologically interesting area, five quantitatively large osteological samples were selected (Figure 7). The sample comprises a minimum of 89 individuals. I will give a short introduction to the archaeological context, as well as to the osteological assemblage, below.



**Figure 7.**

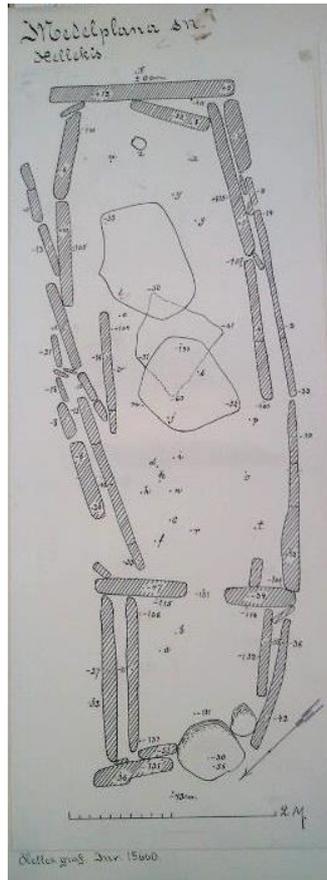
Map of the distribution of five gallery graves from Västergötland. 1= Torbjörntorp 31, 2= Medelplana 54, 3= Österplana 27, 4= Timmersdala 5, 5= Falköping stad 5. Map created using ArcGIS 10.5 by Esri.

### **3.3.1. Berga kalkbrott, Torbjörntorp 31**

The gallery grave at Torbjörntorp 31 outside the town of Falköping was excavated in 1927 by K. E. Sahlström (ATA dnr 3678/1927). The gallery grave was moved to SMR no. Torbjörntorp 30:1 by Hilding Svensson in 1928 (ATA dnr 2863/1928). The gallery grave has a chamber and antechamber, as is common in the area. The grave measured 2.9m × 1.8m and was covered by a low mound of 0.8m with a diameter of 10m. A large quantity of fragmented bones was recovered, adding up to approximately 30 individuals. In addition, four flint daggers, eight heart-shaped flint arrowheads, two flake arrowheads, one shaft-hole axe, one bone awl, one bone chisel, amber beads, a slate pendant, flint scrapers, and pottery were found. A minimum number of 20 individuals—11 adults and nine juveniles—were analysed for this thesis. While I was undertaking the work for this thesis, I was informed that I had not been supplied with the complete material. The additional skeletal material was analysed by osteologist Clara Alfsdotter in 2014. Alfsdotter (2014) determined the Minimum Number of Individuals (MNI), based on the dentition, to be ten: eight adults and two juveniles. The material analysed by Alfsdotter has not been further explored. However, combining Alfsdotter's MNI and the MNI concluded in the work of this thesis, the total MNI is 30, which is consistent with the MNI reported from the excavation.

### **3.3.2. The gallery grave at Hellekis, Medelplana 54:1**

The gallery grave at Hellekis was large at 7.25m × 2.4m and was oriented northeast-southwest (Figure 8). The grave was excavated in 1916 by B. Schnittger for a concrete company since it was situated at the location of a lime-pit. The grave showed indications of looting. The MNI was considered to be as many as 60. The grave also comprised one saw, six daggers, seven arrowheads, three scrapers (all in flint), 20 flint nodules, four slate pendants, and 36 pieces of pottery. A minimum number of 20 individuals—17 adults and three juveniles—could be osteologically analysed within this thesis. This is quite a large discrepancy from the reported MNI from the excavation. However, the MNI estimations from the early twentieth century were not made by osteologists, which is why they should be considered with caution.



**Figure 8.** Drawing of the gallery grave of Hellekis. From the excavation documentation (ATA).

### 3.3.3. Österplana 27:1

A gallery grave was found at Österplana 27:1 in 1885. The grave is not well documented, but five bone needles, one flint axe, one stone axe, two flint daggers, and a few flint chips were found. It is possible that these flint chips were preforms to arrowheads, but this is not mentioned in the documentation. A gable slab and human skulls are in the care of the Swedish History Museum in Stockholm. Crania from seven individuals—six adults and one juvenile—were documented in this thesis. It is probable, but not certain, that no post cranial bones were recovered during the excavation. Only recovering

the crania during excavations were a common practice in the nineteenth century.

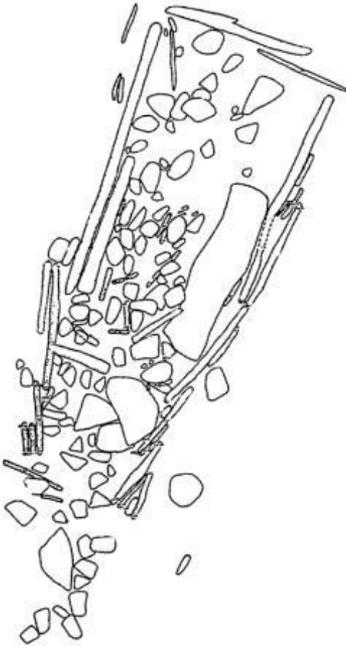
### **3.3.4. Timmersdala 5:1, Skolhuset**

A gallery grave at Timmersdala 5:1 was found and excavated in 1877 during the construction of a new school. The excavation was made by the librarian Karl Torin from the diocese library in Skara. Torin estimated that the grave comprised skeletal remains from at least 100 individuals. In addition to the skeletal remains, two complete flint daggers and one shaft of a flint dagger, nine flint arrow heads, a pierced bear tooth, and pottery were found. During the osteological analysis for this thesis a minimum number of 16 individuals—13 adults and three juveniles—were identified.

### **3.3.5. Fredriksberg, Falköping stad 5**

Falköping stad 5 was excavated and restored in 1973 because of damage induced by construction work (Weiler, 1977). The grave is also known as Fredriksberg and is situated between the two mountains of Mösseberg and Ålleberg. The grave was placed on a small ridge and dug into flat ground. It was constructed of limestone slabs and consisted of a chamber and antechamber, 5.3m × 2m in size and slightly trapezoid shaped, orientated north-north-east to south-south-west (Figure 9). Roof slabs which had collapsed into the grave were found in the chamber. These slabs were covered by stonepacking mixed with soil. The floor consisted of flat limestones. The chamber and antechamber were separated by two limestone slabs with a slit at the top with the antechamber situated a bit lower than the chamber (Weiler, 1977). Artefacts and human and animal bones were primarily found inside the chamber but were also found inside the antechamber to a lesser extent. Most bones found in the grave were from human inhumation, but remains from cattle, sheep or goats, pike, foxes, doves, and rodents were also found (Weiler, 1977). Almost all artefacts were found in the bottom layer and consisted of a decorated ceramic vessel, one flint dagger, 17 flint flakes, six amber pendants, a slate whetter, a bone bead, two bone needles, a bone awl, and a bone flute (SHM 32384). The skeletal remains appeared commingled and were probably moved to make room for new burials. However, there were no indications of disturbances from later dates (Weiler, 1977). Iregren conducted an osteological analysis that pointed

towards a presence of a minimum of 30 individuals: 20 adults and 10 children. Of these, she reported ten being male and seven being female (Iregren, 1977). Five of the individuals were radiocarbon dated when the gallery grave was excavated in 1973 (Weiler, 1977, 23). These analyses were performed by the Laboratory of Radioactive Dating in Stockholm using the conventional method (St no. 5149-53 and 5157) (Weiler, 1977, 23). These dates suggest that the grave was already in use during the MNB (2800–2350 BCE). 21 radiocarbon dates were conducted for this thesis (joint with the doctoral project of Malou Blank, Gothenburg University), suggesting that the gallery grave was in use during much of the LN; no evidence of usage pre-dating this could be found (Table VI).



**Figure 9.** Drawing of the gallery grave at Falköping stad 5. From the excavation documentation (ATA).

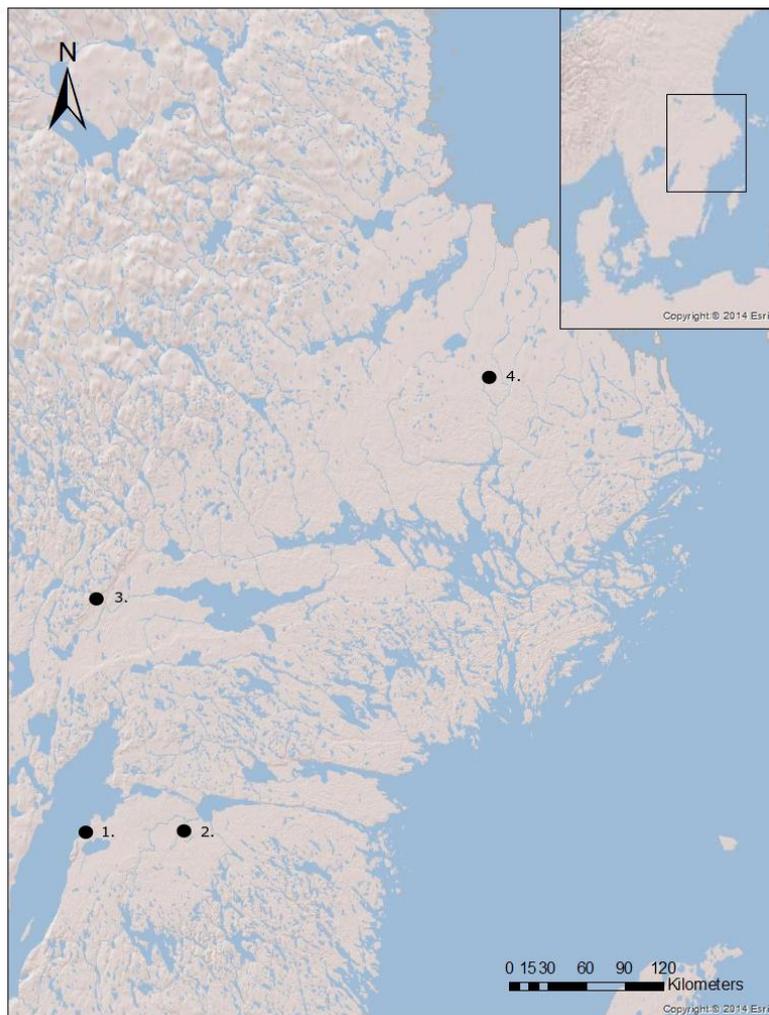
**Table VI.**

Radiocarbon dates of Falköping stad 5 conducted within this project together with the PhD project of Malou Blank, Gothenburg University.

Locality	Grave/Individual	Burial Type	<sup>14</sup> C date BP	<sup>14</sup> C Date (cal.) BCE	Lab no.
Falköping stad 5	F120+132	Gallery grave	3706 ± 36	2202–1980	UBA-30772
Falköping stad 5	F129V2:2	Gallery grave	3697 ± 37	2201–1975	UBA-30762
Falköping stad 5	F128	Gallery grave	3680 ± 33	2192–1960	UBA-30773
Falköping stad 5	F117	Gallery grave	3679 ± 32	2190–1961	UBA-30766
Falköping stad 5	F115VII:2	Gallery grave	3654 ± 34	2137–1940	UBA-30763
Falköping stad 5	F69	Gallery grave	3642 ± 32	2134–1921	UBA-30742
Falköping stad 5	F98	Gallery grave	3640 ± 33	2134–1916	UBA-30774
Falköping stad 5	F132VI:3	Gallery grave	3639 ± 35	2134–1911	UBA-30737
Falköping stad 5	F119	Gallery grave	3638 ± 35	2134–1910	UBA-30771
Falköping stad 5	F134	Gallery grave	3631 ± 42	2135–1891	UBA-30735
Falköping stad 5	F147VI:4	Gallery grave	3624 ± 31	2121–1896	UBA-30745
Falköping stad 5	F88	Gallery grave	3609 ± 41	2132–1880	UBA-30753
Falköping stad 5	F122	Gallery grave	3602 ± 33	2112–1883	UBA-30765
Falköping stad 5	F124	Gallery grave	3600 ± 33	2112–1882	UBA-30775
Falköping stad 5	F139II:2	Gallery grave	3598 ± 31	2031–1886	UBA-30764
Falköping stad 5	F121	Gallery grave	3595 ± 33	2110–1880	UBA-30749
Falköping stad 5	F108IV:3	Gallery grave	3562 ± 49	2030–1756	UBA-30767
Falköping stad 5	F118	Gallery grave	3560 ± 33	2018–1774	UBA-30769
Falköping stad 5	F90	Gallery grave	3500 ± 31	1910–1704	UBA-30758
Falköping stad 5	F123	Gallery grave	3491 ± 33	1902–1697	UBA-30768
Falköping stad 5	F83III:1	Gallery grave	3420 ± 33	1874–1630	UBA-30770

### 3.4. Östergötland, Närke and Uppland

Two localities from Östergötland (Bårstad and Rappestad), one locality from Närke (Lanna Västergård), and one locality from Uppland (Dragby) have been included in this thesis (Figure 10).



**Figure 10.** Map of the gallery graves from southcentral Sweden. 1= Bårstad, 2= Rappestad, 3= Lanna Västergård, 4= Dragby. Map created using ArcGIS 10.5 by Esri.

The material from Östergötland was preserved to varying degrees, but was generally in quite a poor state. In addition, measurements of maximum femoral lengths from a grave in Linköping, associated with the Battle Axe culture in the MNB, were included. The measurements were published in a Bachelor's thesis by Jantsch and Ranåker (2001). An osteological analysis has also been conducted by Nils-Gustav Gejvall (Lindahl and Gejvall, 1955).

There are several known gallery graves from the province of Närke, some of which also contain unburnt human bones. However, the bones are generally poorly preserved and only one of the gallery graves is therefore included in the present thesis. The skeletal remains from the province of Närke were analysed and briefly reported by Fürst (1914).

Uppland, situated 710 kilometres north of the Swedish capital of Stockholm, is on the northern boundary of the area where archaeologists normally find gallery graves which have been associated to the south Scandinavian tradition. These graves rarely contain bones due to poor preservation. Therefore, the well-preserved bones in the gallery grave from Dragby, Skuttunge parish, are of special interest despite the geographical location. The gallery grave of Annelund, Uppland (Fagerlund and Hamilton, 1995), was considered for analysis but was excluded in the initial phase because of poor preservation.

### **3.4.1. Bårstad, Roglösa parish**

The site in Bårstad, Roglösa parish, was excavated by Bengt Cnattingius in 1928. The grave was disturbed since there had previously been a cellar at the site. No grave construction was therefore visible. Skeletal parts were found commingled. Only deeper articulated skeletal remains were found: first, a well-preserved skull, and later, a well-preserved articulated skeleton. Although the soil was sieved in parts, no artefacts were found. In total, a minimum number of 16 individuals—six adults and 10 juveniles—were included in this thesis.

Two radiocarbon dates have been made within this thesis, with one skeleton dated to the LN II, 3520 ± 45 BP, 1965–1735 cal BCE (LuS 11856) and one dated to the EBA, 3295 ± 45 BP, 1685–1490 cal BCE (LuS 11855). It is probable that the skeletons derive from some sort of gallery grave considering the dates and multiple inhumations.

### **3.4.2. Rappestad 22:1**

The grave, a gallery grave with a stone packing, was excavated because of a motorway construction in the 1970s. The stone packing measured 7m × 8m and was 0.4m high. The gallery grave itself measured 6m × 0.7m, with a depth of one metre (ATA dnr. 6250/74). According to the report, the floor of the gallery grave was covered by burnt bones from at least seven individuals. Some pottery and flint objects were also found. Even though they were not described in the report, a number of unburnt bones were also linked to the grave. A minimum number of three individuals—one adult and two juveniles—were included in this thesis.

### **3.4.3. Hidinge, Lanna Västergård**

The gallery grave was excavated by archaeologist Nils Åberg in 1927. The excavation was sought upon after the grave was detected by a farmer during cultivation work. The gallery grave was covered by a cairn approximately 11m in diameter and 70cm high, although partly destroyed by the farmer during his cultivation.

Åberg reported that he found a large assemblage of human bones in the grave (Figure 11). They were mainly discovered in a sandy layer at a depth of 60–70cm and appeared randomly but evenly distributed over the entire layer. The vertebrae, femora, and humeri were fairly well preserved, but all of the skulls are reported to be crushed. With the exception of the human bones, only a few undecorated pottery sherds were found. The gallery grave was restored after the excavation.

Even though reported as being well preserved and numerous, the bone material is in quite a poor condition. It is probable that almost a century in storage has fragmented the bones further still than what was reported in 1927. Unfortunately, this excludes the bone material from some of the analyses otherwise conducted in this thesis. In total, a minimum number of four individuals—three adults and one juvenile—were included in this thesis. Five radiocarbon dates were conducted and placed the use of the grave in the LN II–EBA I (Table VII).

**Table VII.**

Radiocarbon dates from the gallery grave Lanna Västergård in Närke. The dates place the time of use to LN II–EBA I.

Grave/Individual	<sup>14</sup> C date BP	<sup>14</sup> C Date (cal.) BCE	Lab no.
LannaV-G1	3442 ± 35	1880–1664	UBA-30402
LannaV-G2	3327 ± 36	1691–1510	UBA-30403
LannaV-G3	3405 ± 51	1880–1564	UBA-30404
LannaV-G4	3509 ± 48	1956–1693	UBA-30405
LannaV-G5	3417 ± 35	1874–1626	UBA-30406

### 3.4.4. Dragby Gallery grave, Skuttunge parish

The gallery grave (grave 88p) was situated on a grave field alongside an additional 40 (approx.) cremations and one inhumation grave. It was excavated by Uppsala University professor Mårten Stenberger in 1960. The excavation report was written by Ph.lic. Ulla Silvén (ATA Dnr 1324/62), with an additional publication in the Uppsala University archaeological journal, *TOR*, in 1963 (Gejvall, 1963). The grave has also been included in Jan Apel's Bachelor's thesis (Apel, 1991), and stable isotopes from 10 individuals were included in the Bachelor's thesis of Nikos Roumelis (Roumelis, 2002) and later published in Eriksson and Lidén (2013).

The gallery grave, found as a primary grave underneath a cairn, was oriented approximately northwest-southeast with the long sides being somewhat curved in towards a southwesterly direction. The inside of the gallery grave measured 3.2m x 1.1–1.3m and was 0.8–0.9m deep. The stones originally making up the roof of the grave had all collapsed into the chamber. The remaining stones, at least five in number, were quite small and could not have stretched from one long side to the other to form a roof. The archaeological interpretation was that there had probably been a log in the midline on which the covering stones had rested which had collapsed when the timber decomposed. The covering stones were of both granite and limestone which also impacted bone preservation. The limestone slabs were situated in the northwest, covering one-third of the grave. This is also where the best-preserved bone material was found. The difference in preservation between the areas was significant (Silvén, 1962).

A large part of the skeletal remains is reported as being seemingly irregularly scattered throughout the stone cist, with a majority in the northwest. However, the report also concludes that earlier burials had been disturbed and bodies moved around before decomposition was complete since some body parts were found articulated (i.e. parts of a spine with attached ribs and complete extremities). Two individuals were found almost intact, lying in outstretched positions side by side with their heads towards the southeast. These were probably the last individuals to be buried which also led to the rearrangement of remains from earlier inhumations to make room for the new ones. This is clearly visible in the photo documentation (Figure 11). On top of the two articulated individuals a layer of sand and charcoal was found. The charcoal was dated to around 1215 BCE which has to be considered as the ending point of the usage of the grave. This dating also correlates well with many of the grave goods, indicating a LN–EBA dating, although a somewhat earlier double button with a star ornamentation (Montelius per. III) was found in the cist and interpreted as an example of possible burial goods (Silvén, 1962).

Gejvall's analysis included primarily osteometry and estimation of stature (Gejvall, 1963). He estimated the mean male stature to be  $181.4 \pm 0.9\text{cm}$  ( $n=8$ ) and female stature to be  $169.0 \pm 1.5\text{cm}$  ( $n=13$ ). The numbers in brackets indicate the number of measured long bones without any indication of number of individuals. Living stature was estimated using Trotter and Gleser (1952). The reanalysis of stature based on maximum femoral lengths shows the mean male stature to be  $175.9\text{cm}$  ( $n=3$ ) and the mean female stature to be  $167.3\text{cm}$  ( $n=4$ ) (Tornberg, 2015) when using Sjøvold's method.



**Figure 11.**  
Photo plan of the Dragby gallery grave. It is easy to distinguish the latest two burials that were still articulated.  
Photo: unknown. ATA dnr. 3280/58.



# 4. Methods

In this section an overview of the methods applied is provided. Both osteological and biochemical analyses have been conducted and this methods section is therefore divided accordingly. Since a large part of the material is fragmented and commingled, the methodology applied needed to be used pragmatically. In this respect I have been forced to use a minimum number of individuals as a scale of quantification. The MNI was probably first introduced by paleontologists such as Stock (1929) and Howard (1930) who worked with ancient mammals and bird remains recovered from the asphalt lake of Rancho La Brea in California, famous for the rich deposits of Pleistocene fossils. Both writers clearly define the methodology of MNI. Howard also showed great insight into the problem of the method related to taphonomic loss (Howard, 1930, p. 82). The terminology was probably introduced to archaeology by White (1953) as a measure of meat weight provided by each taxon in the past. MNI could be calculated in a complete pooled sample or divided between samples. When it comes to calculations of MNI in this thesis, the MNI has been estimated within each context and thereafter added together. I believe that this creates less bias. The use of the Most Likely Number of Individuals (MLNI) quantification system (Adams and Konigsberg, 2004), where the number of left and right bone elements is divided with the number of pairs, might have provided additional information about the number of individuals in the material. However, the method was considered difficult to apply considering the very different states of preservation in the material and was deemed too time-consuming to undertake in relation to the amount of additional information for this thesis. I am well aware of problems with using MNI as a basis for quantification and that it is probable that the sample really includes more inhumations than suggested by this quantification, especially in highly fragmented assemblages. However, since large parts of the material is commingled, I have decided that approaching the material through MNI will still provide less bias than if I had tried to assess all bones to individuals. Detailed information about the methods applied is given in the individual papers.

## 4.1. Osteological methods

The skeletal material under management of the Lund University Historical Museum was analysed in the museum storage at Gastelyckan, Lund. The material managed by the Swedish Historical Museum was analysed in the osteological laboratory at the Department of Archaeology and Ancient History, Lund University. All skeletal remains were registered in a Microsoft Access 2010 database that was constructed by me for this specific project.

### 4.1.1. Sex estimations

Division by sex has seldom been applicable in the analyses on which this thesis is built. This is due to the commingling of skeletal remains and lack of articulated individuals in the gallery graves. When working with single graves and graves with articulated individuals on the one hand, and gallery graves with multiple inhumations that are commingled on the other, it has been necessary to be pragmatic in the analysis procedure. The commingled bones from gallery graves once also belonged to individuals and therefore have valuable information about the past, although the questions have to be addressed differently than when working with single graves.

Sex estimations have been carried out on all articulated individuals suitable for sex estimation using standard morphological characters of both the pelvis (Phenice, 1969; Milner, 1992) and of the skull and mandible (Acsádi and Nemeskéri, 1970), as suggested by Buikstra et al. (1994). Further, all commingled pelvises, skulls, and mandibles that are non-pathological and of sufficient preservation and have been sex estimated. Morphological characters of the pelvis have been favoured over skull morphology since they have a more direct relationship to reproduction and are not population specific. Metrics based on the assumption of sexual dimorphism have been used for sex estimations in relation to stature estimations. For further details I recommend the metrics section below (4.1.1.3.) or Paper II.

#### 4.1.1.1. Pelvis

The pelvis provides the most reliable data for sex determination since the shape of the pelvis has a function in association with child bearing and child birth in women. For this thesis I have registered the pelvic sex characteristics recommended in Buikstra et al. (1994) which consist of characteristics of

both the pubic and iliac bones. Morphology of the pubic bone is registered in accordance with the method developed by Phenice (1969). The methods include characteristics of the subpubic area: the ventral arc, subpubic concavity, and the ischiopubic ramus ridge. Positive appearance is considered female. The characters were categorized as follows: 1=female, 2=ambiguous, and 3=male. Where possible, characteristics were grouped together for categorisation, as recommended by Phenice (1969) and Buikstra et al. (1994). The morphological characteristics of the pubic area have been further developed by Bruzek (2002), who reports an accuracy of 95%. His method has not been applied in this thesis, however. Characteristics of the pubic area are considered more reliable as sex indicators than those of the iliac bone (Buikstra et al., 1994, p. 18). However, the pubic bone primarily consists of spongy bone which is why the taphonomic loss is greater than for the iliac bone. It is therefore beneficial to also consider characteristics of the ilium.

The greater sciatic notch and the preauricular surface of the iliac bone were considered as sex markers. The greater sciatic notch is wider in females than in males and the preauricular sulcus is considered to be a female trait (Milner, 1992). The registration procedure of the greater sciatic notch included visual comparisons to a diagram of sciatic notch width (Milner, 1992; Buikstra et al., 1994). The sciatic notch is scored 1–5, with scores 1–2 being females or probable females, 3 being ambiguous, and 4–5 being males or probable males. The preauricular sulcus was only registered as either present or absent even though a scoring of the feature with two scores indicating absence (0–1) and three scores indicating presence (2–4) is suggested (Milner, 1992; Buikstra et al., 1994). Novak et al. (2012) used both morphological and metric evaluation of the auricular surface of the ilium, the sciatic notch, and the preauricular surface for sex estimations of the 97 males and 101 females from the William M. Bass and Terry Collections and found accuracy of 94.9% when multiple characteristics were evaluated. Considering the late date of publication, this method was not used in the current work.

#### *4.1.1.2. The cranium and mandible*

Secondary characteristics of the skull related to robusticity have been included in sex estimations, especially in commingled remains where complete individuals are absent. It is greatly important to be familiar with the material when estimating sex since an increased gracilization of the crania is evident from the Stone Age onwards. Working with Stone Age skeletal material one should be aware that female skulls can appear as robust as a male skull from later dates. Registered traits follow the standards of Acsádi

and Nemeskéri (1970) and include characteristics of the nuchal crest (occipital bone), mastoid process (temporal bone), and the supraorbital margin and glabella of the frontal bone. The characteristics are based solely on visual appearance and were scored as 1=female, 2=female?, 3=unknown, 4=male?, and 5=male. This method is also suggested by Buikstra et al. (1994). It is probable that additional information about individual sex based on skull morphology might have been gained through the use of discriminant analysis as suggested by Walker (2008). This methodology was not applied in this thesis but would be interesting to apply in future since it acknowledges population differences in robusticity. In tooth sampling procedures and oral health investigations of commingled remains, morphological features of the mandible were considered for preliminary sex. The sex is estimated in the same manner as the skull and consists of the mental eminence (Acsádi and Nemeskéri, 1970; Buikstra et al., 1994), the gonial eversion (Kemkes-Grottenthaler et al., 2002), and the ramus flexure (Loth and Henneberg, 1996; Kemkes-Grottenthaler et al., 2002). Characteristics of the mandible are to be considered less reliable as sex indicators (Maat et al., 1997); nevertheless, the mandible is one of the most persistent elements often found intact in otherwise in poorly preserved skeletal remains, and which often also contain much information when teeth are preserved.

#### *4.1.1.3. Metrics*

In Paper II, “Stature and the Neolithic Transition– Skeletal Evidence from Southern Sweden,” statistical analysis of sexual dimorphism in femora was used as the method for sex estimation. Estimations were based on measurements of the femoral anterior-posterior (Martin 10), medial-lateral (Martin 9), and vertical diameter of the femoral head (Martin 18) (Martin and Saller, 1957). The measurements were analysed using an Iterative Discriminant Analysis (I.D.A.) as suggested by Van Vark (1974). The discriminant analysis was based on two datasets: one from measurements of MN farmers and one from LN–EBA individuals that could be sex estimated through pelvis morphology. The discriminant analysis was run on each dataset separately, together with the femora of unknown sex. The sex estimates are based on statistical modelling on samples from an individual of known sex from the same context where phenotype is similar. Metric sex estimations have previously been suggested by, for example, Spradley and Jantz (2011) and Garvin (2012). These estimations are based on modern populations, however, and are thus deemed unsuitable for this thesis. When using an iterative discriminant function directly on Neolithic and Bronze Age

materials, the results do not become biased through comparisons to modern data where body proportions might be different. Considering that differences in size were expected between Neolithic and Bronze Age samples, this was considered to be of great importance. However, the method might misclassify sex in the middle range since the iteration continues until all femora have been classified to either sex. This has, however, been proven to be a small problem in practice as long as the discriminatory factor is fairly large (Van Vark, 1974, p. 78f.). Missing values have been imputed using an iterative regression, which is considered as good as, or better, than other missing data approaches (Holt and Benfer, 2000). Replacement of missing values with sample means would decrease the variability and probably increase sample bias. The regression has been carried out using the VIM package in the free statistical software R (Templ et al., 2011a; Templ et al., 2011b).

#### **4.1.2. Estimations of age**

In an almost dystopic article, Bocquet-Appel and Masset (1982) said farewell to paleodemography until new methods could solve the methodological problem of most age estimation models within bioarchaeology. The estimated ages at death of the individuals were not accurate enough for a demographic model to be applied. They also criticized the tendency of ‘age mimicry’ of the reference population, which was often unrepresentative of a normal population. Ever since, bioarchaeologists and paleodemographers have tried to solve this problem, resulting in the Rostock Manifesto for paleodemography after a paleodemography workshop at Max Planck Institute for Demographic Research in 1999 (Hoppa and Vaupel, 2002b), with contributions published in Hoppa and Vaupel (2002a). The Rostock Manifesto presents a theoretical framework of how to continue working with ageing skeletons and paleodemography.

There are seldom any problems in assessing juvenile age since dental and skeletal development is not notably affected by culture. Primarily, dental development has been used when assessing juvenile age according to Schour et al. (1944) and Gustafson and Koch (1974). Secondarily epiphyseal fusion has been used as reported by Schaefer et al. (2009). For infants and juveniles lacking both dental and epiphyseal data, bone measurements have been considered (Schaefer et al., 2009). Dry bone data has primarily been considered. Long bone measurements are more sensitive to cultural surroundings than tooth formation and epiphyseal fusion since nutritional

deficiency and stress can cause growth stunting. Therefore, when possible, other bones, such as *pars petrosus* and *pars basilaris* have been favoured for measurements.

Adult age has been assessed using transition analysis when possible (Papers III, IV, and V) (Boldsen et al., 2002). The analysis is based on registration of morphological characteristics of the pubic bone and the sacroiliac joint, as well as cranial suture synostosis. Transition analysis is based on Bayesian modelling with previously established population demographic patterns. The transition analysis provides better age estimates and is not biased through “age mimicry”. It also enables age estimates above the age of 50 (Boldsen et al., 2002). This approach therefore provides very important information about ageing in prehistoric contexts. The transition analysis was made using the ADBOU software (Boldsen et al. 2002, available at (<http://math.mercyhurst.edu/~sousley/Software/>) with an archaeological population without any known ancestry. However, traditional osteological methods including morphology of the sacroiliac joint (Lovejoy et al., 1985; Buckberry and Chamberlain, 2002) and the pubic bone (Brooks and Suchey, 1990) have been used when applicable. Cranial suture synostosis has not been used in age estimations other than in the separation of old adults from young adults and juveniles, and when used in the transition analysis. Işcan et al. (1984a) developed an age-estimation method based on degenerative changes of the sternal end of the ribs which was found to be relatively accurate. However, in a slightly later study, (Işcan et al., 1984b), they selected the fourth rib for evaluation. It is very difficult, if not impossible, to distinguish the fourth rib from other ribs in severely fragmented and commingled remains so this particular method of age-estimation was therefore not applied in current research. Tooth attrition has been considered as an indicator of approximate age in tooth sampling procedures and dental health registration of commingled remains (see Paper III) and has been registered according to Brothwell (1981).

#### **4.1.3. Registration of dental caries and dental calculus**

Dental caries/tooth decay is caused by acids produced by bacteria breaking down sugar. These acids can lead to the destruction of the enamel, dentine, and tooth cementum, causing a cavity (Hillson, 1996). Evidence of dental caries was investigated macroscopically under a bright light, with a dental probe and magnifying glass when necessary. Only real cavities were

registered as dental caries while discolourations or initial enamel demineralization were not. Dental caries was registered as 1=occlusal surface, 2= interproximal, 3=smooth surface, 4=cervical caries, 5=root caries, 6=large caries with unknown origin, 7=non-carious pulp exposure, 0=non detectable and 9=non observable. Liebe-Harkort et al. (2010) conclude that osteologists tend to underestimate dental caries whereas odontologists overestimate caries rates. Liebe-Harkort (2012) further found exceptional rates of dental caries in Iron Age Smörkullen, central Sweden, mostly in the form of shallow lesions. Liebe-Harkort et al (2010, 2012) argue that dental caries have a large impact upon health. I agree with this to some extent; dental caries do affect general health and could also provide information about dietary habits. However, I do not agree that initial caries have this effect. I further argue that it is probable that a large percentage of initial caries and small lesions remain undetected in the osteological record, skewing the results, and have therefore chosen to only register visible cavities.

Dental calculus is the result of mineralized plaque and is the main reason for gingival disease leading to alveolar bone resorption (Hillson, 1996). The etiology of dental calculus has been discussed but is thought to be dependent on both genetic predisposition and diet (Lieverse, 1999). A protein-rich diet is thought to increase the risk of dental calculus (Hillson, 1996). Lieverse (1999) argues that the risk of dental calculus increases with a protein-rich diet since protein raises the alkalinity in the oral cavity which is beneficial for plaque formation. The amount of dental calculus can therefore provide information about both the diet (direct or indirect, see Paper III for further information) and periodontal disease. Dental calculus in this study was observed macroscopically and was scored 1–3 (slight, medium, severe), 0 (absent) and 9 (non-observable).

#### **4.1.4. Stature estimations**

Throughout this thesis human stature is based on measurements of the maximum length of the femur (Martin 1) (Martin and Saller, 1957). Stature estimations can be conducted using all long bones but the lower limbs are preferred since they actually contribute to living stature. Generally, the more the bone contributes to living stature, the better it predicts stature (Ously, 2012). This relationship is the reason that the femur, being the longest bone in humans, is known to best correlate to living stature. The femur is also

robust, which makes it one of the most frequently occurring complete long bones in skeletal assemblages. All long bones suitable for measurement have, however, been registered in the database for this thesis. When referring to stature, it is the maximum femoral length which is referred to, while calculated stature is referred to as living stature. All measurements were taken on femoral bones with fused proximal and distal epiphysis to guarantee completed growth. Primarily, the left femur was chosen, with the right femur included only when the left femur was missing or not measurable due to fragmentation. A digital caliper with an accuracy of 0.03mm and an osteometric board were used. All measurements have been rounded to the closest two decimals. When referring to calculated living stature the method of Sjøvold (1990) has been considered. The method is based on organic correlation from a range of different populations generally neutralising ethnicity, instead of using the least square regression formulae calculated from modern populations, as is the case for Trotter and Gleser (1952). Sjøvold's method is known not to underestimate tall individuals or overestimate short individuals. Methods based on least square regression of modern populations might also be biased by secular trend, for example, the difference in mean stature in a population from one generation to another, where bones of the lower limb are longer in relation to stature than bones not affected by secular trend (Stinson, 2012). However, the most accurate method for stature estimations is not based on statistic modelling but on a measurement of the complete skeleton in the grave (Petersen, 2005; Boldsen, 1984) or through the anatomical method (Fully, 1956; Fully and Pineau, 1960). These kinds of stature estimations have not been possible due to the material being commingled, fragmented, and, to a large extent, having been recovered in the early 1900s.

#### **4.1.5. Paleopathology**

Paleopathology has been registered for all bones as present, absent, or non-observable. Pathologies were then described in the database and, when possible, diagnosed primarily using standard paleopathology literature such as Waldron (2009), Aufderheide et al. (2011), and Roberts and Manchester (2005). Paleopathological focus in this thesis is related to malnutrition and stress (enamel hypoplasia and cribra orbitalia), and skull trauma. Skull trauma and care have been analysed in Paper V while signs of stress are discussed in relation to general health in Paper III.

The long-term term effects of skull trauma and care were analysed using the Index of Care. The Index of Care is largely divided into four steps of documentation and interpretation. The application is web-based and is accessible through <http://www.indexofcare.org/> and this is where individual cases are documented and interpreted. The four steps are divided as follows:

Step one: Describe, diagnose, document

Step two: Determine disability

Step three: Construct the model of care

Step four: Interpretation (Tilley and Cameron, 2014).

This means that the skeletal remains and all paleopathological and additional features are documented, described, and diagnosed in the first step. In the second step an interpretation of disability is constructed, for example, identifying the pathological condition's impact on everyday life. In the third step the degree and type of care needed for the affected is evaluated. In the last step an interpretation of the implications on the individual and collective is made. For further insight into the Index of Care I recommend the website and the guide written by Tilley and Cameron (2014).

## 4.2. Biochemical analyses

The biochemical analyses in this thesis consist of radiocarbon dates and the stable isotopes of  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  for dietary reconstruction. Radiocarbon dates and isotope analyses have been made on a selection of the available material. All bones that have been analysed for dietary reconstruction have also been  $^{14}\text{C}$  dated at the same laboratory. Further, analyses of  $^{87}\text{Sr}/^{86}\text{Sr}$  for indications of mobility have been applied to a gallery grave in Falbygden and are presented in Paper III.

### 4.2.1. Radiocarbon dating

In total, 96 radiocarbon dates were produced within the thesis project. 52 individuals from Scania, 27 individuals from a gallery grave from the province of Västergötland, five individuals from the province of Närke, and two individuals from the province of Östergötland have been dated to the LN

and EBA. In addition, one individual was dated to the late MNB, and nine animal samples were dated to the LBA. The majority (n=81) of the dates were established by the <sup>14</sup>Chrono Laboratory at Queens University in Belfast while remaining samples (n=15) were sent to the Department of Geology at Lund University. Selections have been made in consideration of bone preservation, the possibility for archaeological relative dating, attempts to “close contexts” (i.e. finding out the time span in which the grave was used), site sample size, geographical spread, and archaeological significance.

#### *4.2.1.1. Sampling strategies*

The majority of the samples that were sent for radiocarbon dating were also selected for isotope analysis which affected the sampling strategies. The goal was to sample individuals from all burial types so that it would be possible to discuss any chronological differences in burial types. Important sampling strategies for both radiocarbon dates and for isotope studies included being certain to only sample each individual once, as well as leaving out pathological bones. For details I recommend section 4.2.2.1. Individuals that could not be tied to particular chronologically definable burial goods were selected for radiocarbon dating to a larger extent than the individuals who were buried with typologically datable artifacts. Accordingly, individuals inhumed in flat burials and gallery graves were selected more frequently than individuals in Bronze Age barrows. I have also tried to date as many individuals as possible at each site, depending on both the degradation of the skeletal remains and the amount of finances available. In the Falköping stad 5 gallery grave and the gallery grave in Lanna Västergård all identifiable individuals could be selected.

#### *4.2.1.2. Sample preparation*

The radiocarbon dates conducted at the <sup>14</sup>Chrono Laboratory were pretreated as follows. The collagen in the samples with a laboratory number below UBA-24991 was extracted through the modified Longin method (Longin, 1971) developed by Brown et al. (1988) using a Vivaspin filter cleaning method (Ramsey et al., 2004) and an additional cleaning step where 90°C water was used for pretreating ultra-filters. Further, samples with a laboratory number above UBA-24991 were pretreated using a simple ABA treatment followed by gelatinization and ultrafiltration with a Vivaspin filter cleaning method (Reimer et al., 2015). All <sup>14</sup>Chrono laboratory datings have been undertaken by Accelerator Mass Spectrometry (AMS) and all radiocarbon ages have been calculated using online <sup>13</sup>C values measured using the AMS

(Reimer et al., 2015). This is done to see the natural isotopic composition in the sample and to catch fractionations that have occurred during the laboratory or dating processes (Reimer et al., 2015). This meticulous pretreatment reduces the risk of contamination to the absolute minimum, making the dating very reliable.

In addition to the radiocarbon dates conducted at the <sup>14</sup>Chrono Laboratory, some radiocarbon dates were done by the Department of Geology at Lund University. These samples have laboratory numbers starting with LU.

Bone samples are first mechanically cleaned and then pretreated with NaOH to remove humic and other organic impurities. Collagen is extracted using a modified Longin method (Longin, 1971; Brock et al., 2010). For samples conducted after 2013, the Department of Geology also provided additional quality control through the use of the sample C:N ratio (Brock et al., 2012). For very old bone samples and samples of obviously poor quality an ultrafiltration cleaning step was added. Although not all samples have been cleaned by ultrafiltration, the datings conducted at the Department of Geology are considered reliable, especially those post-dating 2013 when the quality control of C:N ratio was introduced. All dates included in this thesis are conducted from 2013 and later.

#### *4.2.1.3. Calibration*

All dates have been calibrated using the online version of Oxcal 4.3. Radiocarbon calibration in Oxcal software is based on dendrochronological data (Reimer et al., 2013). Calibration could also be made by the presence of clearly dated artefacts. The reservoir effect, meaning the inclusion of carbon from another reservoir than the atmospheric, i.e. lakes and oceans, would make the sample look older. Skeletons could get affected by reservoir effect by a high dietary intake of aquatic resources during life. A marine sample would have an age approximately 400 years older than a terrestrial one (Stuiver and Braziunas, 1993). This could be detected and compensated for by analysing the <sup>13</sup>C value. The reservoir effect has not been considered to be problematic in this study since there is little indication of marine or fresh water fish in the diet according to the stable isotope analysis.

#### 4.2.2. Stable isotopes $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ for dietary reconstruction

In total, 38 individuals from Scania, five individuals from the province of Närke, and 28 individuals from a gallery grave in the province of Västergötland, all dating to the LN–EBA, have been analysed for dietary reconstruction using  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values. In addition, one individual dating to the late MNB, associated to the Swedish-Norwegian Battle Axe culture (c. 2800–2300 BCE) included in Paper IV, and nine animal samples dated to the LBA from the locality of Sandeplan, Scania, were included.

Analyses of stable isotopes have become a commonly used source of information of subsistence and dietary habits in a number of archaeological studies. Carbon and nitrogen isotope ratios in human bone collagen can be used to estimate part of prehistoric food consumption (Sealy, 1986; 2001). The levels of the carbon and nitrogen isotopes largely reflect the protein contribution to the diet (Ambrose and Norr, 1993; Schwarcz, 2002; Jim et al., 2004). The level of  $\delta^{13}\text{C}$  reflects whether the diet was based mainly on terrestrial or marine resources (Van der Merwe 1982; Schoeninger and DeNiro, 1984), with levels lower than  $-20\text{‰}$  considered entirely terrestrial and up to  $-12\text{‰}$  as entirely marine in northern Europe (Eriksson and Lidén, 2013). The levels of  $\delta^{15}\text{N}$  refer to the trophic level, with enrichment along the food chain commonly reported as about  $3\text{‰}$ , resulting in animals preying on herbivores having values of about  $9\text{‰}$  on land (e.g. Schoeninger and DeNiro, 1984; Eriksson and Lidén, 2013). The marine ecosystem is somewhat different, allowing for more trophic levels and therefore higher  $\delta^{15}\text{N}$  values (Schoeninger and DeNiro, 1984). The enrichment of  $\delta^{15}\text{N}$  has been debated and is today considered higher and might vary within and between species (O’Connell et al., 2012). Higher and more varied enrichment of  $\delta^{15}\text{N}$  have been considered in recent publications (Wilhelmson, 2017b; Hedges and Reynard, 2007). O’Connell et al. (2012) measured enrichment in collagen as high as  $6\text{‰}$ , resulting in a general overestimation of animal protein in past human populations if a standard of  $3\text{‰}$  is used. Enrichment of  $5\text{‰}$  was also applied by Wilhelmson (2017b) who challenged previous interpretations made by Eriksson et al. (2008) of a high marine contribution in the diet on Iron Age Öland on the Swedish east coast. In the studies within this thesis only raw data is presented which makes the enrichment of  $\delta^{15}\text{N}$  unproblematic here.

However, the interpretation of diet from stable isotopes can be affected by a number of other things that are not related to the question of enrichment. It is of importance to acknowledge that there are, for example, a number of

factors that can lead to increased  $\delta^{15}\text{N}$ . Children who are still breastfed get  $\delta^{15}\text{N}$  values one trophic level higher than the woman who is breastfeeding them since these children are actually preying on the breastfeeding women. The same is true for consumption of juvenile herbivores. Physiological stress, famine, and the intake of manured crops could also lead to increased  $\delta^{15}\text{N}$  values (Hedges and Van Klinken, 2002; Fraser et al., 2011; Eriksson, 2013, 130, 136).

#### *4.2.2.1. Sampling strategies*

All samples were taken from visibly non-pathological bone. Some pathologies, especially osteomyelitis, are known to change the stable isotope composition of the affected area and its surroundings (Katzenberg and Lovell, 1999; Olsen et al., 2014). The recommendation is therefore not to sample pathological bone and to sample individuals with pathologies with caution (Katzenberg and Lovell, 1999). Since a majority of the material originates from commingled remains, only sampled elements—not the complete skeletons—have been considered in terms of pathologies.

The samples from the Scanian material have primarily been extracted from the mandible, but in a few cases the humerus was selected when mandibles were missing. The humerus was sampled on the distal diaphysis where bone is compact. Cortical bone was chosen for analysis since it has a slower turnover time than trabecular bone and is generally recommended for isotope sampling (e.g. Grupe, 1988; Jørkov et al., 2009). In three cases, permanent teeth (one premolar, one lower first molar, and one upper first molar) were used. The Närke, Östergötland and Falköping stad 5 samples were all teeth, reflecting childhood diet. It is unlikely that any of the permanent teeth that were sampled were from individuals pre-weaning. All mandibles and the humerus mirror the diet in the last ten years or so while the teeth reflect childhood diet. For details on the teeth sampled, I refer to the articles. Even though it is possible that diet changes between childhood and adulthood, there is nothing in the examined material to suggest such a change.

All analyses of dietary isotopes were conducted at the  $^{14}\text{C}$ Chrono Centre in Belfast. All Scanian samples were selected from individuals post-weaning. All samples included had a C:N ratio between 2.9 and 3.5 as is generally recommended to avoid diagenetic bias (e.g. DeNiro, 1985; van Klinken, 1999).

#### 4.2.2.2. Sample preparation

The collagen extraction was the same as for the UBA samples in section 4.2.1.1. The samples were further measured for %C, %N,  $\delta^{13}\text{C}$ , and  $\delta^{15}\text{N}$  on a Thermo Delta V elemental analyser - isotope ratio mass spectrometer (EA-IRMS). The samples and standards were combusted in an elemental analyser (%C, %N) and isotopes ratios were measured in the IRMS. The standards that were used for stable isotopes ( $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ ) in collagen were IA-R041 L-Alanine ( $\delta^{15}\text{N}$ ,  $-5.56 \pm 0.14\%$ ;  $\delta^{13}\text{C}$ ,  $-23.33 \pm 0.10\%$ ), IAEA-CH-6 Sucrose ( $\delta^{13}\text{C}$ ,  $-10.449 \pm 0.033\%$ ), and IAEA-N-2 Ammonium Sulphate ( $\delta^{15}\text{N}$ ,  $+20.3 \pm 0.2\%$ ), as well as a fish bone standard (Fish) for quality control ( $\delta^{13}\text{C}$ ,  $-31.44$ ;  $\delta^{15}\text{N}$ ,  $+17.78$  ( $n > 100$ )). For collagen 8-10 replicate measurements for R041, three replicates for IAEA-N-2, three replicates of IAEA-CH-6 and five replicates of Fish are standard (Reimer et al., 2015).

#### 4.2.3. Strontium isotopes

Strontium isotope analysis was included only in Paper III and has primarily been the focus of the research of the co-authors Blank and Knipper. I will therefore only provide a brief introduction to strontium isotope analysis here, and recommend Paper III or the works of Knipper et al. (2012) and Blank and Knipper (forthcoming) for further reading. The strontium isotope analysis was undertaken by Knipper at the Curt-Engelhorn-Center for Archaeometry in Mannheim, Germany, following Knipper et al. (2012).

Strontium originates from weathering rock minerals and is integrated in the chemical composition of the human skeleton through food and drink (Bentley, 2006). The bioavailable signature of  $^{87}\text{Sr}/^{86}\text{Sr}$  is reflective of the  $^{87}\text{Sr}/^{86}\text{Sr}$  value of the geology from where the food and drink originates (Faure, 1986) and can therefore be used as an effective method to analyse prehistoric mobility. The geological  $^{87}\text{Sr}/^{86}\text{Sr}$  signal depends on the original ratio of Rb/Sr (as  $^{87}\text{Rb}$  radioactively decays into  $^{87}\text{Sr}$ ) and the geological age of the weathered rock

(Faure, 1986). There are, however, factors that can affect the strontium isotope concentration and ratio other than the underlying geology, such as sea spray, heavy rains, and areas of glacial deposits (Bentley, 2006; Montgomery, 2010; Frei and Price, 2012). If the water and foods that people ate were locally produced the bioavailable strontium isotope ratio would thus reflect the geological area where they resided when alive (Montgomery,

2010, p. 325). The bioavailable strontium ratios are then compared to a baseline of mapped geological  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios. In Sweden, baselines are presently only available in a few areas (Sjögren and Price, 2006; Frei, 2009; Sjögren et al., 2009; Fornander et al., 2015; Price et al., 2015; Wilhelmson and Ahlström, 2015; Eriksson et al., 2016; Wilhelmson and Price, 2017; Price et al., 2017, 2018; Blank and Knipper, forthcoming). However, the isotope values of Falbygden are relatively well known (Sjögren et al., 2009; Sjögren and Price, 2013). These studies show a clear division of the Cambro-Silurian area (Falbygden) and the surrounding Precambrian bedrock. The isotope signal of the bioavailable strontium in Falbygden ranges from 0.713 to 0.716 whereas the surrounding Precambrian areas show higher ratios ranging from 0.719 to 0.726 (Sjögren et al., 2009; Sjögren and Price, 2013).

Strontium isotope analysis was made on tooth enamel. Tooth enamel is often preferred as it is less susceptible to diagenesis and contamination (Bentley, 2006; Montgomery, 2010, p. 329). Enamel is inert and does not remodel. This makes the bioavailable strontium isotope signal reflective of childhood strontium isotope uptake (Hillson, 1996). This could then be compared to the local geological signal where the individual was buried as a point of departure for discussing prehistoric mobility.



# 5. Overview of the individual papers

In the following chapter I give a short overview of the individual papers. The research questions in the papers correspond to the research questions outlined in section 1.1, and together they provide results related to the aims of the thesis.

## 5.1. Paper I

“Diet, Toothache and Burial Complexity. Tracing Social Status through Bioarchaeological Methods in Late Neolithic–Early Bronze Age Scania.” *Lund Archaeological Review* 22 (2016).

In this paper, social differences were targeted through bioarchaeological methods. The paper explored the question of whether the heterogeneity in burial customs traditionally associated with the south Scandinavian LN and EBA (inhumations in flat graves, gallery graves, and barrows) was related to a difference in chronology, and whether there were differences in dietary isotope values between individuals buried in these different grave types that could not be explained by chronology.

To answer this question, 50 new radiocarbon dates from 50 individuals were analysed. The radiocarbon dates showed that there was an increase in burial heterogeneity from the LN I to the EBA, culminating in the EBA II. In the LN I, all individuals (n=11) were inhumed in flat burials. There was also a strong resemblance between these burials and the preceding Battle Axe culture burial tradition. In Scania, people started to erect gallery graves in around 2000 BCE, corresponding roughly to the LN II. However, the majority (68 %) of burials in Scanian gallery graves are from the Bronze Age (Table VIII). This is a much larger proportion than expected. In the EBA the mound burials were also introduced. Throughout the LN and EBA, the

practice of flat burials remained, although to a lesser extent than in the LN I. The LN II flat burials often also comprise more than one inhumation.

**Table VIII.**

Summary table of the frequency of the different burial types associated to the three studied periods.

	Flat earth	Barrow	Gallery grave
<b>LN I</b>	11	0	0
<b>LN II</b>	6	0	7
<b>EBA</b>	3	8	15

To evaluate whether there were dietary patterns that could be connected to the difference in burial practice, stable isotopes of carbon and nitrogen were analysed in 29 of the individuals from the LN II–EBA, and the amount of dental caries was also assessed in a data set of 598 post-canine teeth. Burials from the LN I were excluded since the burial practice is to be considered homogenous in current material. The nitrogen values were relatively high, indicating that manuring might have been practiced during the period. However, no statistically significant differences in  $\delta^{13}\text{C}$  or  $\delta^{15}\text{N}$  values between burials were present. This lack of statistically significant differences suggests that the protein contribution to the diet was similar for all individuals. There were, however, differences in dental caries, where the highest number was present in mounds (9 %, n=109) and the lowest in gallery graves (4.2%, n=397). Flat burials had intermediate frequency rates of dental caries (6%, n=124). However, the difference between the highest and lowest caries rates was not statistically significant (p=0.0818). Statistically significant results are very hard to gain in small samples, and are thus rare within archaeological investigations, which makes the visual difference in dental caries, as well as the relatively low p-value of 0.0818, all the more interesting despite statistical non-significance. This difference in rates of caries might reflect a higher carbohydrate contribution in the diet among individuals buried in mounds. However, this is not reflected in the stable isotopes. Mound burials are often richly equipped and generally considered to be high-status graves (Håkansson, 1985). Holst et al. (2013) suggest that only around 20% of the population would have gained a mound burial. The rest of the population was previously un-detected. Radiocarbon dates in Bergerbrant et al. (2017) and in this paper show that the rest of the Bronze Age population—the ‘commoners’—were buried in gallery graves and in flat burials, at least in Scania. Considering this, it is possible that the elevated rates of dental caries in mound burials reflect a habit of eating or drinking foods sweetened with honey, i.e. the consumption of luxury foods. A honey-

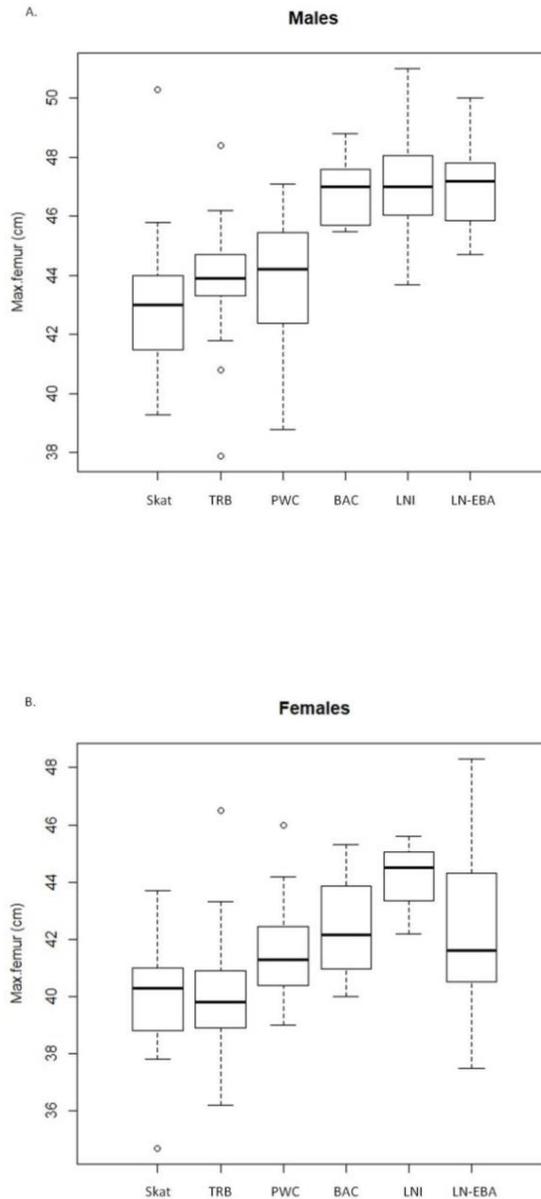
sweetened beverage was also found in a grave in the contemporary Danish Egtved burial (Denmark National Museum). It is argued that different types of burials are associated with different social levels of society, but that there is not a higher meat consumption or visibly different food behaviour among individuals interpreted as members of the ‘elite’. However, elevated rates of caries in mound burials might be reflective of the consumption of luxury foods, such as honey.

## 5.2. Paper II

“Stature and the Neolithic Transition– Skeletal Evidence from Southern Sweden.” *Journal of Archaeological Science: Reports* 17 (2018).

In Paper II, I examined maximum femoral lengths from 203 individuals dating to the Late Mesolithic through the EBA to evaluate whether there was a change in stature following the transition to agriculture, and if LN stature in southern Sweden was equally as high as those reported from Denmark. In what way has male and female stature developed from the Mesolithic to the EBA in southern Sweden?

Since much of the femora were impossible to assess to specific individuals, traditional sex estimations were not possible in those cases. By using measurements of the vertical diameter of the femoral head, femoral anterior-posterior and medial-lateral sex was instead statistically determined on the basis of sexual dimorphism through iterative discriminant analysis, as suggested by van Vark (1974). Maximum femoral lengths were then analysed using non-parametric testing.



**Figure 12.**

Boxplot of maximum femoral length for A: males and B: females. Outliers are marked with circles. Ska=Skateholm (Late Mesolithic); TRB=Funnelbeaker Culture (Middle Neolithic A) PWC=Pitted Ware Culture (Middle Neolithic A-B foragers); BAC=Battle Axe Culture (Middle Neolithic B); LNI=Late Neolithic I; LNII-EBA=Late Neolithic II-Early Bronze Age. It is evident that there is an increase in male statures in association to the Battle Axe Culture that then remains more or less static throughout the Late Neolithic and Early Bronze Age. Female stature is increasing gradually throughout the Neolithic but decreases somewhat in the latest part.

The results confirm statistically significant differences in femoral lengths between culture groups in southern Sweden. It is clear that male stature increases in an event-like manner in the Battle Axe culture and then remains more or less static throughout the LN and EBA. There is no clear difference in stature following the Neolithic transition around 4000 BCE. Female stature does increase throughout the Neolithic, but in a more linear way. However, female stature then seem to decrease in the LN II–EBA (Figure 12).

It is well known that high stature is highly correlated to good nutrition and health. However, a new influx of genes could also contribute to increased stature, although only marginally (Stinson, 2012, p. 601). Recent aDNA results suggest a new influx of genes, probably associated with the Yamnaya culture in the east, around 3000 BCE (Allentoft et al., 2015; Haak et al. 2015). This new genetic signal is visible in skeletons from the Battle Axe culture onward. Individuals of the Yamnaya culture have been associated with high stature (Mathieson et al., 2015) and might contribute to the high stature in south Sweden from this period onward. However, the genetic signal of the Yamnaya is higher in continental Europe than in Scandinavia, but the stature is much lower (Wittwer-Backofen and Tomo, 2008), indicating that there are other factors that are influential on stature in south Sweden. Bogin (1999) argues that stature is more dependent on environmental factors (health, disease, social setting, etc.) than on genetic ones. Consequently, the answer to the increase in stature in the Battle Axe culture is probably more complex than being only to the result of a genetic influx. Very high stature is evident in the wealthiest countries in the world in the present day, and continues to increase as nutrition standards and health care improves (Roberts and Manchester, 2005). There are strong archaeological indications of an intensified agro-pastoral economy during the LN. A pastoral subsistence is linked to a higher reliance on secondary products, such as milk. Milk consumption is proved as a significant contributor to both a higher average BMI among African pastoralists (Iannotti and Lesorogol, 2014) and a higher average stature among modern Swedish children and adolescents (Almon et al., 2011). The lactose found in fresh milk also has qualities resembling that of vitamin D which helps the small intestine to resorb calcium (Durham, 1991), which is beneficial for health. Allentoft et al. (2015) found a higher level of lactase persistence (the genetic ability to digest milk in adulthood) in Corded Ware individuals than in previous European populations, indicating an increased reliance on dairy products as nutrition. This is also supported by zooarchaeological assemblages, at least from the later part of the Bronze Age (Vretemark et al., 2010). Putting all of this together, I argue that the high

stature throughout the Battle Axe culture through to the EBA is more a result of increased nutrition than a new genetic influx. Considering this, it is also possible that the decrease in female stature in the LN II–EBA is a result of social and economic stratification. Only one of the females sampled is buried in a grave that fits the criteria necessary to be deemed ‘high status’. It is possible that because the majority of the LN II–EBA female samples were comprised of individuals from a lower social status, differences in dietary habits and possible inferior health might have been present and might thus have influenced the result.

### 5.3. Paper III

“New Perspectives on the Late Neolithic of southwestern Sweden. An interdisciplinary investigation of the Gallery Grave Falköping stad 5.” *Open Archaeology* 4 (2018).

Co-written with Malou Blank, Gothenburg University, and Corina Knipper, Curt-Engelhorn-Center for Archaeometry in Mannheim.

In contrast to Paper I and Paper II, Paper III explores a single locality through the application of multiple bioarchaeological methods, instead of a single method on multiple localities. The paper is co-authored with Malou Blank, a PhD candidate in Archaeology at Gothenburg University, and Corina Knipper, researcher at Curt-Engelhorn-Center for Archaeometry in Mannheim. We addressed the question of whether the LN megalithic population in Falbygden is similar to the megalithic MN population, or whether there are differences revealing a change in society.

The methodology of the paper is interdisciplinary and based on a combination of archaeology, osteology, and various isotope analyses. The geological conditions and richness of megalithic graves in Falbygden are suitable for studies of Neolithic human remains. Despite this, the LN period (2350–1700 BCE) was poorly studied. The aim of the paper was to gain new knowledge of the LN megalithic population in Falbygden and to conduct in-depth osteological and archaeological studies focusing on one single gallery grave (Falköping stad 5). A minimum of 28 individuals were inhumed in the grave. Of these individuals, 21 were  $^{14}\text{C}$  dated and analysed for carbon, nitrogen, and strontium isotopes. These 21 individuals correspond to the number of individual mandibles that could be identified.

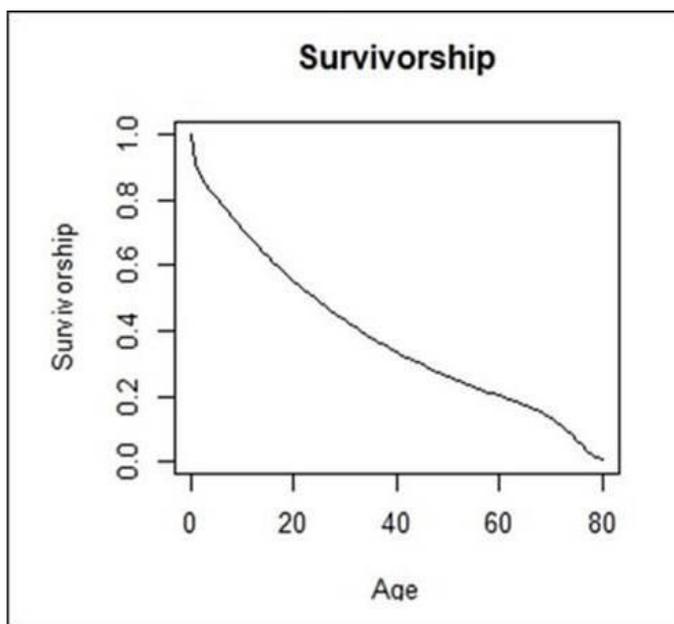
Adult age was assessed using transition analysis using the ADBOU application (Baldsen et al., 2002). Paleodemography was modelled using a Siler competing hazard model (Siler, 1979, 1983; Wood et al., 2002). The analysis of dietary isotopes was conducted at the <sup>14</sup>Chrono Centre in Belfast. The samples were pretreated using a simple ABA treatment followed by gelatinization and ultrafiltration with a Vivaspin filter cleaning method (Reimer et al., 2015). Enamel sample preparation and Strontium isotope analysis were carried out by Corina Knipper at the Curt-Engelhorn-Center for Archaeometry in Mannheim, Germany, following Knipper et al. (2012).

<sup>14</sup>C results showed that the grave was already in use during the first part of the LN and was probably used in two different phases by different groups. The <sup>14</sup>C analyses suggest the grave’s usage time to be 100–500 years.

It is clear that a large proportion of adults died in young years, but that those who survived lived to old ages (Table IX). The Siler analysis further showed a very high residual component to mortality, which reduced the number of individuals relatively even throughout the life-span (Figure 13).

**Table IX.**  
Age at death distribution using transition analysis.

Point value	Low	High	Sex
20.0	15.0	26.2	M
20.0	15.0	26.2	M
20.0	15.0	28.0	F
20.0	15.0	28.0	F
20.0	15.0	28.0	F
26.5	26.5	58.0	F
35.2	15.2	69.9	M
43.0	21.8	77.3	F
75.3	45.3	90.3	M
75.3	45.3	90.3	M
72.8	30.3	90.0	F
78.1	44.9	92.5	M



**Figure 13.** Survival of the Falköping stad 5 population using a Siler competing hazard model.

Dental caries was present in 8% of post-canine teeth and signs of general stress in the form of enamel hypoplasia were found in 28.6% of the individuals, mostly on the canines. Cribra orbitalia was completely absent in the sample.

The diet isotopes suggest a terrestrial diet with  $\delta^{15}\text{N}$  values somewhat lower than for MN samples in the area. Collagen-apatite spacing is also consistent with a herbivorous rather than a carnivorous diet. Further, analyses of ancient protein preserved in dental calculus from six individuals in Falköping stad 5 provide direct evidence of dairy consumption (Fotakis et al., forthcoming). This probably indicates a heavier reliance on cattle, which could also explain the decreased  $\delta^{15}\text{N}$  values in the LN in relation to the MN samples. Strontium isotopes suggest that a large proportion of the inhumed (38%) were non-locals. Another 33% fell into an ambiguous category, while only 29% display a signal consistent with the Falbygden area. The local signal of the Falbygden and surrounding areas was based on baselines reported in previous studies (Sjögren and Price, 2006; Frei, 2009; Sjögren et al., 2009; Sjögren and Price,

2013; Fornander et al., 2015; Wilhelmson and Ahlström, 2015; Eriksson et al., 2016; Wilhelmson and Price, 2017; Price et al., 2017, 2018; Blank and Knipper, forthcoming).

## 5.4. Paper IV

“The Paleodemography of Late Neolithic–Early Bronze Age Agropastoralists from Southern Sweden.” Submitted to *Open Archaeology*.

The general assumption has long been that prehistoric people died young and that a low number of children present in skeletal assemblages is a result of taphonomic loss (Lewis, 2007). In this paper, I have used transition analysis for age estimations and modelled demography using a Siler competing hazard model in a pooled LN–EBA skeletal sample from southern Sweden. The results were compared to other populations. Would the use of transition analysis make it possible to find individuals older than 50 years of age in the LN–EBA population? To what extent does the demographic model based on a skeletal population from the south Scandinavian LN–EBA correspond to the comparative populations? Which stressors might have affected the demographic profile of the south Scandinavian LN–EBA population?

The results show that the majority of adult deaths actually occurred between the ages of 70 and 80 and that LN–EBA mortality has the closest resemblance to the mortality pattern of rural parish of Junsele in northern Sweden. Looking at the Siler model, it is evident that the LN–EBA sample is characterized by low rates of child mortality and a high residual mortality that provides a constant attrition to the population. Low child-mortality rates are generally considered to be biased by taphonomic loss in archaeological assemblages and it is probable that the LN–EBA sample suffered from some taphonomic loss in those of the youngest ages, considering that most of the graves were excavated in the late nineteenth century and the first half of the twentieth century when the bone material was not a priority among archaeologists.

However, the main reason for child mortality is infection (Black et al., 2008; Roberts and Manchester, 2005). Infections need to affect approximately 5000 individuals in order to sustain for any lengthy time (Cockburn, 1977, p. 109). The living population in Lund, St Laurentii parish, was 2750 in 1749 and 1128 in Jokkmokk parish the same year. Junsele parish, on the other hand,

was only inhabited by 238 people in 1758 (TABVERK, CEDAR, Umeå University). When comparing the Siler models, it is evident that the populations with the highest relative child mortality also have the largest population. High rates of child mortality are thus density dependent.

Notable, and non-existent in either of the other populations, is the high mortality rate among adolescents and young adults in the LN–EBA sample. All the other samples have a very low risk of dying in the early adult years. Considering the high proportion of trauma in Neolithic and Bronze Age central and northern Europe, it is probable that much of this mortality can be explained by conflict-related deaths, perhaps because of territorial disputes and population pressure.

## 5.5. Paper V

“Care and Consequences of Traumatic Brain Injury in Neolithic Sweden: A case study of ante-mortem skull trauma and brain injury addressed through the bioarchaeology of care.” *International Journal of Osteoarchaeology* (2018). <https://doi.org/10.1002/oa.2646>

Paper V is co-written with neuropsychologist Lars Jacobsson (PhD) and addresses the question of care in relation to heavy skull trauma and traumatic brain injury in a male individual associated to the Swedish-Norwegian Battle Axe culture. The paper is case-based and seeks to evaluate in what way biological conditions, in relation to social setting, affect the outcome of a traumatic brain injury. What kinds of problems can these injuries result in and what kind of care would have been necessary for the individual’s outcome, both in the acute phase as well as in the long term? The case has been evaluated using the Index of Care as described by Tilley and Cameron (2014). This methodology is also further explained in sections 2.1.3.1. and 4.1.5.

The male suffered from two traumas to the head. The appearance of the injuries suggests that they might have been caused by blows from a battle axe (Figure 14). Both traumas showed evidence of significant healing.



**Figure 14.**

The skull traumas of the individual from Östra Torp 4. A frontal trauma appears to fit neatly with the edge of a battle axe (a) and a parietal trauma fits well with the neck of a battle axe type D (b). Photos: Anna Tornberg.

We found that the society must have provided different kinds of care, both in the acute phase and in the long term. In the acute phase, rudimentary care was available, such as the use of basic hygiene. Considering the neat healing of the wounds, the lack of any signs of infection, and long-term survival, some sort of surgery and care for the wound in clean environments was probably carried out. The traumatic brain injury probably caused problems with spatial orientation. This would have had a direct social impact upon the individual since the Battle Axe culture is often associated with a relatively high degree of mobility. It is likely that the individual would have needed help from others to be able to function within a nomadic society. The trauma might also have had an impact on handling sequences in more complex activities, especially in the case of any new learning, where long-known, routine performances could not be generated as help for executing a task. The individual would also probably have needed help in planning ahead.

Even though the individual must have had a changed role within the society following the trauma, there is nothing in the archaeological record to suggest any deviant treatment, for example, differences in burial practice. It seems as if the individual could remain a functional part of the Battle Axe culture society, perhaps through changed responsibilities. We acknowledge this as evidence of the Battle Axe culture society being socially sustainable. A socially sustainable society could be expressed as one in which *“the basic conditions that are necessary for the [...] social systems to not systematically degrade, so that the opportunity to meet needs remain”* (Missimer, 2015, p. 41). In a society where all individuals would have played

an important role for sustaining enough nutrition and possibly protection, caring for them in the best possible way would have been one of the basic conditions. It is difficult to encourage parts of the society to contribute if the contribution would not provide some sort of guarantee for care when needed. Caring for one individual's survival and re-socialization would thus be a necessity for the survival and maintenance of the group.

# 6. Discussion

In this thesis I have put forward interpretations of LN and Bronze Age societies through the lenses of bioarchaeology. Through the direct study of human remains, a part of the actual population of these societies can provide information about the life and death within them. The purpose of the papers has been to highlight different themes concerning diet and health that together add to the understanding of the formation of Bronze Age society in southern Sweden and the life within these societies. The LN and EBA in southern Scandinavia are interesting periods in terms of changes in political-economy, considering the development towards a more political and economic diversity which is visible through the archaeological material. Inherent in the term *hierarchies* is political and economic inequality. As introduced in section 2.3.1., political-economy and social differences can be addressed through a bioculturally oriented bioarchaeology and the study of nutrition and responses to nutrition, disease, and pathology. The biological (in this case skeletally detectable) response to the political-economic situation could either be adaptation (positive response) or stress (negative response). Analysing these responses provides exclusive information about the political-economic situation that is not readily detectable through traditional archaeological methodology and within material culture.

As presented initially in this thesis, the skeletal responses to the Secondary Products Revolution (Sherratt, 1981, 1997, 2004) and further the rise of a political and economic unequal and specialized, i.e. complex society, at the latest in the EBA, are analysed within this thesis. The tight relationship between complex societies and the Secondary Products Revolution has been argued by both Sherratt (1981) and Earle (1989). Through the Secondary Products Revolution there is a possibility for economic surplus. This accumulating surplus could then be used in trading which would generate a further surplus, as well as the possibility to gain prestige items. The Secondary Products Revolution would thus mean that there is affluent access to nutrition. High access to nutrition would thus contribute to a positive biological adaptation in the population. However, when social and economic

differences are developed, this affluence might be available to only a few individuals. This leads to the second situation, namely that of inequalities in social status between groups of individuals. In a society which is politically and economically unequal there are plausible systematic differences in biological responses within the populations. Patterns in these differences could further function as a point of departure in a discussion about the elite and ‘commoners’.

One of the goals of my research has been to establish knowledge not only of the individuals forming the elite, but also of these ‘commoners’. Although settlement archaeology in recent years has generated valuable knowledge of settlement patterns and discussions about ‘commoners’ and the elite (Artursson, 2009; Artursson et al., 2010; Brink, 2013;), the ‘commoners’ have been lacking in burial archaeology. There has long been an understanding among archaeologists that only one part of the EBA population was buried in mounds—the wealthiest part (Håkansson, 1985; Holst et al., 2013)—but the lack of extensive radiocarbon dates of skeletal remains in gallery graves meant that archaeologists were unaware of the high number of EBA inhumations. The earlier undetected skeletal remains of commoners now seem to have been found in these gallery graves, as is argued by Bergerbrant et al. (2017) and in Paper I. Thus, exploring LN and Bronze Age societies through the human remains does provide information and possible understandings of both ‘commoners’ and the elite that might otherwise be undetectable in other sub-fields of archaeology.

There is no easy understanding of the complexity of the formation of Bronze Age society, or, indeed, of any society. Nevertheless, this is also one of the most important archaeological understandings, and is thus well addressed by Heyd (2017). There are several biases that need to be taken into account. The skeletal and artifact materials that are found in archaeological contexts are not perfect reflections of the living or the deposited material as they have been altered and partly destroyed through the history of time; in other words, they are taphonomically biased. This is one of the reasons why research has focused on the elite in the Bronze Age; monuments and bronzes have better resistance to taphonomic agents than organic material and are thus more visible thousands of years after deposition. It seems clear, however, that not all of the population could be of the elite, since the elite are, by definition, uncommon. Although there could be parts of the population that were not inhumed in graves, a bioarchaeological approach is ideal to find both the ‘commoners’ and the elite in skeletal assemblages. As long as the study

includes different kinds of burials, bioarchaeological methodology does not discriminate.

The importance of metals and metal trade (Vandkilde, 1996; Kristiansen, 1999; Earle, 2002; Kristiansen and Earle, 2015) and agro-pastoral intensification and the Secondary Products Revolution (Sherratt, 1981; Earle, 1989; Sherratt, 1997; Greenfield, 2010, p. 31) have probably both been important and necessary for the formation of Bronze Age society. Whether an agro-pastoral intensification or the trade of metals is seen as the most important trigger for the development of Bronze Age societies, scholars place the development of a complex society in the Neolithic (Apel, 2001; Artursson, 2005; Kristiansen, 2006; Brink, 2009, p. 351) or in the EBA Ib–II (Vandkilde, 1996; Kristiansen, 1999; Earle, 2002; Kristiansen and Earle, 2015). I argue that both of these departures follow on from each other and that long-distance metal trade would not have been possible without the Secondary Products Revolution. The technological and agricultural innovations connected to the Secondary Products Revolution made trade and distribution of metals possible. Thus, the foundation of a Bronze Age society is closely connected to both an intensification of agriculture and to the distribution of metals. I believe that there is bioarchaeological evidence to support this point of view, which I develop further below.

For the structure of the discussion, I would like to revisit the aims of this thesis, which I introduced in section 1.1. The aims were explored through the different research papers. They were:

- i.) To evaluate diet, subsistence, and possible dietary variations in the LN and EBA;
- ii.) To provide evidence for health, health changes, and care in Neolithic and EBA southern Sweden using a holistic approach;
- iii.) To model a paleodemographic profile for LN–EBA southern Sweden;
- iv.) To address past social relations using bioarchaeological methods.

Below, I will discuss the results of this thesis corresponding to each aim separately. I will then end with a joint discussion of the thesis's contribution to the archaeological understanding of the LN and EBA in southern Sweden.

## 6.1. Diet, subsistence and the Secondary Products Revolution

As presented in the background chapter (section 2.3.1.1.), the Secondary Products Revolution is not concerned with the initial utilization of a specific secondary product, as it has been accused (Greenfield, 2010), but the shift in focus from meat to secondary products production and consumption, and the rise and maintenance of complex societies (Sherratt, 2004). There are also examples of complex societies which do not have a reliance on secondary products, such as complex societies in the *New World* (Sherratt, 1981). However, the role of secondary products in the mechanization of agricultural practice, the provision of new staples, and in supporting long-distance trade has been crucial for developing a surplus and creating new contacts and labour division and, in the long run, led to industrialization. Zooarchaeological remains generally support a shift from meat towards milk and wool production in the Chalcolithic (Greenfield, 2010). Based on the first findings of loom weights and changes in dress jewellery in the south Scandinavian LN and EBA, Luise Ørstedt Brandt concludes that the utilization of sheep wool has probably originated in the LN, but seems to be fairly uncommon until the Iron Age (Ørstedt Brandt, 2014). This is in line with zooarchaeological evidence of slaughter patterns for sheep (Vretemark et al., 2010, p. 155) and geographical origin of Bronze Age wool (Frei et al., 2017). Despite efforts, Ørstedt Brandt could not map a wool trait through aDNA analyses since the trait is affected by many genes, and the preservation for DNA in the examined bones turned out to be low (Brandt, 2014, p. 111 ff). This is unfortunate since such a map would have provided valuable knowledge about the utilization of sheep for secondary products.

In 1969, biomedical researchers found out that a majority of African-descendant American teenagers and adults (73%) were unable to digest fresh milk, whereas the same frequency of European descendants was only 16% (Durham, 1991, p. 228). We now know that the ability to digest milk sugar (lactose) in adulthood is a relatively frequent genetic mutation correlated to high reliance on pastoral subsistence, a gene-culture co-evolution (Feldman and Cavalli-Sforza, 1985; Durham, 1991). The ability to drink milk depends on a genetic mutation that makes the production of the enzyme that cleaves the disaccharide lactose into monosaccharides, namely lactase, persist into adult age, making the individuals lactase persistent (LP) (Flatz, 1987; Ingram et al., 2009). The most common genetic mutation is a allele of a C/T

polymorphism located 13,910 basepairs (bp) upstream the lactase gene (Enattah et al., 2002; Ingram et al., 2009; Coelho et al., 2005). The evolution and connection of lactase persistence in association to pastoral subsistence has been examined in a vast number of publications (e.g. Hollox et al., 2001; Myles et al., 2005; Burger et al., 2007; Itan et al., 2009; Malmström et al., 2010; Leonardi et al., 2012) and it is also probable that the lactase persistence gene has been introduced in different populations at different times (Enattah et al., 2007).

We know that the genetic ability to digest milk sugar is infrequent in the MN and LN–EBA skeletal assemblages in northern Europe (Burger et al., 2007; Malmström et al., 2010; Allentoft et al., 2015). Even though these studies rest on a low or moderate number of samples and there is a small increase in lactase persistence in the Corded Ware culture (Allentoft et al., 2015), it is likely that lactase persistence has mainly been genetically selected for on a later date. The reason for the rapid genetic selection in favour of the lactase persistence gene in Scandinavia is still not concluded. However, there are strong indications that the fresh milk also has qualities that make it act like vitamin D. Vitamin D helps the small intestine to resorb calcium (Durham, 1991) which is, of course, beneficial for health and bone development. Fresh milk could have been of great importance during the dark winters when access to vitamin D from the sun was low. When fresh milk is used in cheese or yoghurts, the proportion of lactose is markedly reduced which makes it less beneficial for calcium resorption but allows dairy products to be available for lactase non-persistent individuals. This kind of preparation also allows for the possibility of storing milk products for a lengthier time than would be possible for fresh milk. The focus towards secondary products is intimately connected to a shift in focus from agriculture to pastoralism. Evans-Pritchard noted that among the pastoralist Nuer of Sudan, fresh milk was mainly drunk by children, while adults drank their milk soured or ate it as millet porridge or soft cheese (Evans-Pritchard, 1937, p. 220). It is probable that this reflects a low rate of lactase persistence among the Nuer and it is plausible that milk has been consumed in the same manner in LN–EBA southern Sweden. Analyses of ancient protein from dental calculus sampled from six individuals from the gallery grave Falköping stad 5 evidenced dairy consumption of fresh milk, soured milk, or soft cheese (from cows) in at least three of the individuals, but most probably all six of the sampled individuals (Fotakis et al., forthcoming).

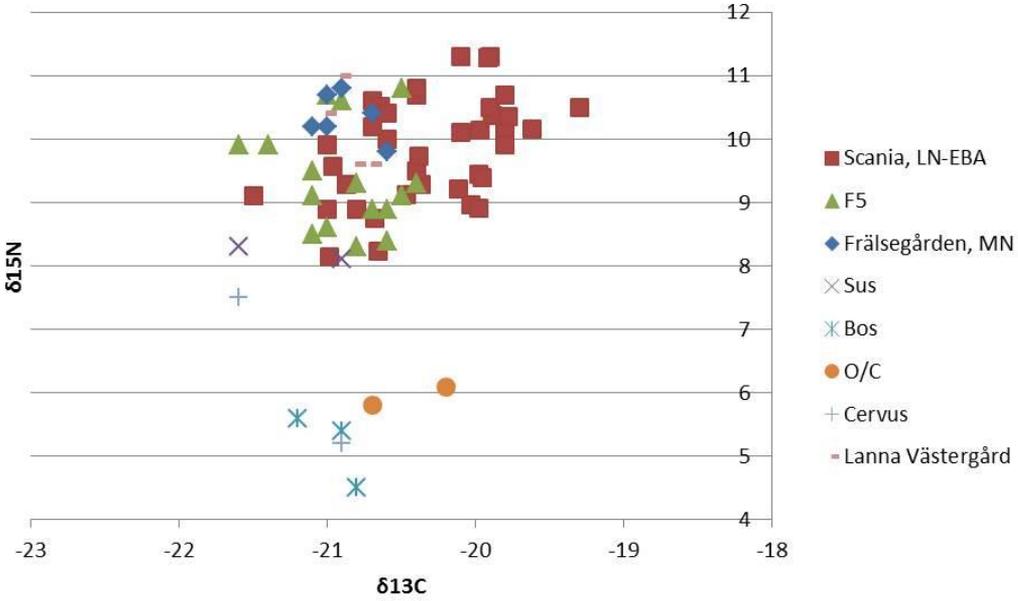
There is strong evidence to support an increased reliance on agro-pastoralism, beginning in the LN. The culmination of deforestation in the LBA began already in the MN and increased throughout the LN and EBA (Digerfeldt, 1975; Berglund, 2003; Vretemark et al., 2010, p. 159) and is clear evidence of the necessity for new grazing and cultivation areas. Macrofossil analysis from fire pits in Denmark shows that wood was no longer used as fuel; instead, bog peat, twigs and branches from bushes, and animal dung were used. Even the houses in Thy were built from poor timber material (Vretemark et al., 2010, p. 159). These pieces of evidence point to a problem with heavily reduced forests. Experiment-based analysis suggests that the use of bones as fuel creates better radiation heat than wood (Théry-Parisot, 2002) and that such a use of bone has been suggested in prehistoric contexts (Théry-Parisot, 2002; Williams et al., 2017). Considering the wood crisis suggested by Vretemark et al. (2010) and the low amount of zooarchaeological finds from the LN–EBA, the use of animal bones as fuel for heat is a possible explanation for this phenomenon. New areas were populated during the LN, which is probably associated with population increase (Apel, 2001, p. 11; Apel and Knutsson, 2004). However, a shift in subsistence towards pastoralism made new areas which had not been rich enough for cultivation productive as pastures, and the use of manure, together with the use of early ploughs, enriched unfertile soils so that new areas could be sown and thus populated (Sherratt, 1981).

As presented in section 2.1.3.2., zooarchaeological assemblages dating to the LN–EBA are largely missing, and only a few very small samples are available. These materials are too small to be considered indicative for subsistence, however. Animal bones dating to the MN are predominantly from sheep or goats, followed by pigs (Malmer, 2002, p. 145ff; Sjögren, 2017). Sjögren (2017) shows that the domestic pig (osteological analysis made by Maria Vretemark) adds up to 55% of the number of identified specimens in the animal bone assemblage of Landbogården, Falbygden area. Cattle are represented by the second largest assemblage of 22%. During the Bronze Age a shift in focus towards cattle is seen with a sex and age distribution supportive of increased reliance on milk cows and working oxen (Vretemark et al., 2010, p. 155). The importance of cattle is further highlighted through the use of ox-hides in Danish oak-coffin graves from the EBA (Jensen, 2002, p. 173) and the many examples of depicted cattle on Bronze Age rock carvings (Swedish Rock Art Research Archives). It seems as if cattle were important as a base of nutrition but also socially and sacrally (Fokkens, 1999). Evans-Pritchard document this importance also for the

pastoral Nuer of Sudan (Evans-Pritchard, 1937). The higher reliance on cattle relative to sheep and goats could also be explained by Optimal Foraging Theory (OFT) (MacArthur and Pianka, 1966; Emlen and Emlen, 1975; Pyke, 1984) since there is more caloric output from each invested caloric input for cattle than for sheep or goats. Nutrition, social relations, and religion were probably entangled and thus inseparable during much of prehistory. Kristiansen (2006) also argues for cattle being 'hard currency' during the Bronze Age, which explains their presence in different religious and social arenas. Cattle would thus function as a demonstration of power. In the LBA, however, the trend seems to move back towards an increased reliance on sheep, and in some cases pigs (Vretemark et al., 2010, p. 155). It is possible that this is a sign of further specialization and labour division in the LBA, and possibly also increased domestic wool production, as suggested by Ørstedt Brandt (2014). It can also depend on a renewed reliance on agriculture and abandonment of a pastoral lifestyle. While grazing areas dominated in the EBA (Kristiansen, 2006), Häggström (2005) suggests that cultivation increased throughout the Bronze Age and culminated in the Iron Age. Macrofossil samples from Tanum, southwestern Sweden, provide further evidence that systematic manuring of permanent fields was not present until the LBA (Vretemark et al., 2010, p. 161).

Both the analyses of stable isotopes for dietary reconstruction and the amount of dental caries (Paper I and Paper III) support the increased reliance on cattle and, in parts, the increase in carbohydrate ingestion with a moderate level of dental caries in LN–EBA southern Sweden. The stable isotopes of Falköping stad 5 (Paper III) and Scania (Paper I) display both lower  $\delta^{15}\text{N}$  values and a larger variation in both  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  than in the MN sample from Frälsegården in Västergötland (Figure 15). The Scanian sample is more varied while the Falköping stad 5 sample is more constricted in regards of  $\delta^{13}\text{C}$  values. It is probable that this is at least partly due to the Scanian material deriving from multiple localities with different geographical conditions (e.g. differences in levels of manuring, sea spray, etc.) but also the close vicinity to the coast, allowing for the availability of marine foods; both materials from Västergötland are, in contrast, from single inland localities. The difference in variability could also depend on sampling strategies. The Falköping stad 5 consists of tooth samples while the Scanian material is primarily sampled from the mandible. It is possible that dentine, which does not remodel, displays a more homogeneous signal than bone, which continuously remodels. All plotted values are raw values and no calculation of fractionation has been made, which makes the values unaffected by the

problems of fractionation level (O’Connell et al., 2012). Although there is a substantial overlap between the MN and LN samples, there are tendencies towards a reliance on food from a lower trophic level in the LN than during the MN. However, parts of the Scanian sample also show signs of a mixed terrestrial-marine dietary contribution and, as a result, higher trophic levels. It is possible that this reflects a heavier reliance on cattle than pigs, but it could also reflect an increased reliance on plant-based food. When comparing the Västergötland LN and MN materials, the LN samples display higher standard deviations, indicating that diet differed more between individuals in the LN than in the MN. It is probable that this is partly due to an increased source of nutrition but it is possible that this also reflect differences in diet between different social groups or an increased specialization.



**Figure 15.** Scatterplot of stable carbon and nitrogen isotopes for diet reconstruction. A marine contribution to the diet is visible in the Scanian material. Data from Frälssegården from Hinders (2011), Lanna Västergård (Närke province), Falköping stad 5 and Scania, this thesis, and faunal data from the locality Sandeplan, Scania province (<sup>14</sup>C-dated 2890 +/- 52-2753 +/-45 BP, UBA-30563-UBA-30571), sampled for this thesis.

Although still at a low frequency, 8% of the registered post-canine teeth from Falköping stad 5 (Paper III) showed evidence of dental caries. In Scania, the percentage of affected teeth varied between 4.2% and 9% depending on

burial type, the lowest percentage being from gallery graves and the highest from barrows, and the majority deriving from skeletons dated to the EBA (Paper I). The frequency of dental caries from MN agro-pastoralists is commonly around 3% (Ahlström, 2003). Considering this, the proportion of carbohydrates in the form of cereals seems to have been higher in LN–EBA foods. This is also supported by the apatite-collagen spacing from Falköping stad 5. The mean collagen-apatite spacing is 6.3‰ for all permanent teeth. This corresponds more closely to a herbivorous diet rather than a carnivorous one (Lee-Thorp et al., 1989). However, one individual, an older male, displayed substantially higher collagen-apatite spacing than the other individuals (9.1‰). The individual also had a low  $\delta^{15}\text{N}$  value of 8.3‰, indicating a high reliance on plant-based food. Although there is stable isotope evidence that indicates a relatively high plant contribution to the diet, the amount of dental caries in both LN–EBA samples is, however, much lower than what has been reported from, for example, LN Germany where 50–60% of the individuals were affected (Bennike et al., 2007) or Iron Age southeastern Sweden (Liebe-Harkort, 2012). From the locality of Smörkullen in Östergötland, an astonishing 46.2% of analysed teeth were affected by dental caries (Liebe-Harkort, 2012). The comparison might weaken a little since the methodology of Liebe-Harkort also included the registration of initial caries. Together with the LN data from Germany, where agriculture rather than pastoralism was the primary subsistence, it is plausible that this distinct difference in the rate of caries actually reflects the fact that agriculture as primary subsistence was not practiced until the LBA or Early Iron Age in southern Sweden, and that cultivation was secondary to animal husbandry throughout the Neolithic and EBA. Although high reliance on agriculture might not have been present until the LBA or Iron Age, both bioarchaeological and archaeological evidence supports an agro-pastoral intensification in the LN and EBA.

## 6.2. Health following the Secondary Products Revolution

It has been difficult to assess health through paleopathological studies for this thesis. Although presence and absence of different pathological features have been recorded throughout the registration process, there have been rare possibilities to track pathological bones to single individuals. To be able to

assess general health status within a population, parameters such as age, sex, number of the total individuals at risk, and multiple pathological features have to be linked, in accordance with the osteological paradox (Wood et al., 1992; Cohen et al., 1994; Robert and Manchester 2005, p. 28; DeWitte and Stojanowski, 2015). However, the paleopathological features of cribra orbitalia (i.e. porosity in the orbital roof) and enamel hypoplasia, thought to reflect anaemia or vitamin deficiency and general health stress respectively, have been included in Paper III, where focus has been on the gallery grave Falköping stad 5. Further, health has been approached through stature analyses (Paper II) and through the discussion of trauma, care and neuropsychological dysfunction (Paper IV) as well as paleodemography (Paper V). Paleodemography is further discussed in section 6.3. The aim of the paleopathological studies has been to evolve the traditional ‘counting system’ of pathological features, which rarely provides any insight into past populations and societies, towards a more holistic approach to population health. Studies have been conducted on both an individual and populational level. At an individual level, the effect of pathology, both for the single individual and the society in which she lived, has been more significant than the number of affected individuals (Roberts, 2011, p. 254). At a population level, health changes and health differences have primarily been addressed through modelling of demographic data and changes in adult stature across a longer time-frame, even though traditional descriptive frequency statistics of enamel hypoplasia and cribra orbitalia have also been carried out.

The discussion about the aetiology of cribra orbitalia is still present, with some favouring the traditional iron-deficiency anaemia hypothesis (Waldron, 2009; Roberts and Manchester, 2005, p. 230ff) and others the vitamin C/D deficiency hypothesis (Wapler et al., 2004; Walker et al., 2009). Considering that the problem of iron-deficiency anaemia does not cause bone marrow hypertrophy, I consider haematomas in relation to vitamin C/D deficiency or even inflammations more probable causes, although these pathological changes might better be explained as multicausal. Interestingly, as presented in section 5.2.1., cribra orbitalia is not present at all in Falköping stad 5. Although present in south Sweden, the frequency of cribra orbitalia there seems to be generally low, where the frequency is 7.7% in Scania Abbeås (Tornberg, 2013). It is probable that the daily amount of vitamin D could be provided solely by sunlight in the summer. In order to gain a sufficient amount of vitamin D from the sun, being outdoor with naked arms for just 15 minutes, two-three times a week, would be enough in June and July (National Food Agency, Sweden). The rest of the year, vitamin D could be gained

through fish, eggs, wild mushrooms, dairy products, and meat. Fish, wild mushrooms and eggs are all rich in vitamin D while dairy products and red meat have lower levels. However, as presented in section 6.1., the lactose in fresh milk has similar qualities for calcium resorption as vitamin D and might therefore have functioned as a substitute during the winter months. Stable isotopes do not suggest a high intake of fish, even though there are difficulties in targeting freshwater fish through stable isotopes (Katzenberg, 2011; Boethius et al., 2017). However, a combination of fish, meat, eggs from wild birds, and wild mushrooms, is a probable source of vitamin D from foods. Vitamin C is available in fruit, berries, and vegetables. It is probable that berries and apples were gathered during season and that some vegetables were cultivated. However, since vitamin C is water-soluble, the majority of the vitamin disappears in the drying process, making dried fruit and berries low in vitamin C. It is therefore probable that it was difficult to gain enough vitamin C during the winter and spring, making vitamin C deficiency a possible cause of *cribra orbitalia* in prehistoric contexts.

It is somewhat unclear to what extent the presence of enamel hypoplasia in Falköping stad 5 actually mirrors periods of health or nutritional stress. The majority of enamel hypoplasia is present only on the canines, which, according to Bennike et al. (2007), should be regarded as a sign of tooth crowding or local nutritional deficiency. However, two out of eight affected individuals did not survive past the age of 12, which means that at least in these two cases it is probable that the presence of enamel hypoplasia mirrored actual periods of stress, causing early death. The frequency in the Falköping stad 5 material is rather high, with 28.6% of the individuals affected. This could be compared to the Abbekås, where only 15.4% of the individuals had developed enamel hypoplasia (Tornberg, 2013). Although speculative, it is possible that the fact that a majority of the individuals included in the Abbekås study were associated with high-status burials in barrows, and were likewise associated to the EBA and not the LN as in Falköping stad 5, might have had an influence on enamel hypoplasia frequencies. There are strong indications that nutritional stress, rather than disease, is the main cause of enamel hypoplasia (Roberts and Manchester, 2005, p. 76). Even though it is plausible that factors such as differences in chronology and variations in preconditions such as, for example, population density between regions are main contributors to the difference in frequencies of enamel hypoplasia between Falbygden and Scania, it is also possible that differences in social status might have contributed.

There has been a general understanding among osteologists that LN and Bronze Age individuals were tall. The mean male stature of almost 180cm has been suggested (Gejvall, 1963; Bennike, 1985; Tornberg, 2013, 2015). Reports of decreasing stature following the agricultural transition has, however, been reported from other parts of the world (e.g. Cohen and Armelagos, 1984; Wittwer-Backofen and Tomo, 2008). It is known that following the development of stature over time can provide important and adequate information about health changes over time (Steckel, 1995). Growth retardation in juveniles is often due to immediate stress, while underdeveloped adult stature is associated with chronic conditions and is thereby a better measurement of general stress (Goodman and Martin, 2002, p. 19). Although strongly correlated with health, differences in stature can also depend on new genetic influx caused by migrations. Steckel (1995), however, argues that this has only a minor effect on stature. Further, inbreeding is known to generate lower stature (Roberts and Manchester, 2005, p. 41), generating lower stature in sparsely populated areas.

There is no difference in stature following the Neolithic transition (c. 4000 BCE) in southern Sweden, but there is a clear increase associated to the Swedish-Norwegian Battle Axe culture in the MNB (Paper II). These high statures then remain more or less constant throughout the LN and EBA. It is probable that this reflects a non-dramatic transition to agriculture around 4000 BCE. The Ertebølle foragers of southern Scandinavia had been neighbours to farmers of the Funnelbeaker culture for a thousand years and were accustomed with the practice. The transition to agriculture in southern Scandinavia should be viewed as a gradual transition over a few hundred years, where dependence on foraging strategies remained side by side with agriculture (Sørensen, 2014). There is no overlap between the percentiles of the early and late male statures. However, an exception to the stasis in stature is that female stature decreases markedly in LN II–EBA. The variance in values is also at its highest. It is possible that this difference is related to worse living standards for females during this period. The increase in stature evident in the Battle Axe culture is probably dependent on many factors. Recent aDNA research provides evidence that there has been a new genetic influx around 3000 BCE (Haak et al., 2015; Allentoft et al., 2015) which might also have had an influence on stature. The authors of these studies derive this genetic signal to the areas of the eastern steppes, an area that at that time was inhabited by people who archaeologists, through their study of the material culture, recognize as the Yamnaya culture (Haak et al., 2015; Allentoft et al., 2015). Mathieson et al. (2015) propose high stature among

the Yamnaya, based on aDNA. If the assumption that large numbers of individuals associated with the Yamnaya culture holds true, it is possible that genetic high stature among these individuals has contributed to the increase in stature also in southern Sweden. Ancient DNA results also suggest that most of the migrants were males (Goldberg et al., 2017; Kristiansen et al., 2017) which could in such case explain why male stature increases in a more event-like manner than female stature. However, if this genetic influence is the sole explanation for stature increase, the mean stature in continental Europe should be higher than in southern Sweden considering that the new genetic signal is higher in continental Europe than in Scandinavia (Allentoft et al., 2015; Haak et al., 2015) . However, this is not the case (Paper II).

Many scholars have suggested a population increase in the LN. As inbreeding would influence stature negatively, population increase and exogamy would be beneficial for stature. Ahlström (2015) suggests a low population density in the LM and among MN foragers, which would increase the risk for inbreeding which would, in turn, lower stature. It is possible that this kind of higher genetic variability, possibly helped by immigration, was at least partly responsible for the high stature following the Battle Axe culture. However, Steckel (1995) considers good nutrition and health to be a better explanation for increased stature. Considering the intensification of agro-pastoralism, and as pastoral subsistence is linked to a higher reliance on secondary products that provides nutrition (dairy) all year round without the loss of stock, it is probable that this too was beneficial for stature. Milk consumption is proved as a highly significant contributor to higher BMI among children in modern African pastoralist societies (Iannotti and Lesorogol, 2014), as well as higher stature among children and adolescents in modern Sweden (Almon et al., 2011) and Japan (Takahashi, 1984). I argue that the increase in stature following the Battle Axe culture cannot be explained as the outcome of a single factor but should be regarded as the effect of several factors, presented above, each of which was beneficial for high stature.

It is well known that violence has not been an uncommon feature of prehistory. Fibiger et al. (2013) report violence-related trauma to the head and mandible to be 9.4% and 16.9% in Neolithic Sweden and Denmark respectively. Traumatic injury is especially interesting in relation to the development of the Bronze Age society considering that at the top of the hierarchy in these societies is thought to be warrior elites. Wars within Bronze Age societies have in recent years also been supported through bioarchaeological investigations. The most famous is probably the mass

burial of Tollense in northern Germany, where at least 100 individuals with a large number and great variety of peri-mortem injuries were buried at a single event around 1200 BCE (Jantzen et al., 2015). However, Fyllingen (2003) also reports evidence of a mass grave following a battle from Bronze Age Norway.

The majority of the Neolithic assemblages from Sweden investigated by Fibiger et al. (2013) are MN. There is thus little insight into LN and Bronze Age violence in Sweden. My focus in this thesis, however, has not been to further count the number of individuals affected by trauma. Instead, an evaluation and discussion of the effect of trauma for the individual and the past society was carried out. The aim was to highlight the implications of trauma and care in past social relations and societies. This would help deepen the understanding of illness and disability in the past. This approach to paleopathology and health in past societies has been put forward by Judd and Redfern (2011) since it seeks to understand the interplay between individuals and to illuminate social relations. Preliminary results from a forthcoming paper on LN and EBA skull trauma suggest skull trauma frequencies to be approximately the same as in MN southern Sweden (Tornberg, forthcoming). However, in this paper the mandible is not included.

Considering that somewhere between 10–20% of the Neolithic skeletal assemblage have signs of head trauma, there must have been a large number of individuals suffering from brain injuries following the trauma. From a case study of a male individual associated to the late Battle Axe culture buried in Östra Torp 4 in southernmost Sweden, we could conclude that he probably suffered from traumatic brain injury (Paper V). Although the individual from Östra Torp is associated with the Battle Axe culture in the MNB, the late date of the grave makes it probable that the social setting and the technological and medical skills of the time were similar to those of the LN. The injury would have caused short-term unconsciousness and immobility and resulting problems with motor and fine motor skills on the right side of the body in the acute phase. As a result, the individual would have required help with rudimentary activities such as grooming. In the long term, he would probably have had problems with spatial orientation and handling sequences in more complex activities, especially in new learning. We could document two blunt force traumas, one on the right frontal and one on the left parietal, which showed positive correspondence with the edge and neck respectively of a battle axe of Malmer's type D. The individual showed well-developed healing and probably survived for years. The neat healing of the traumas

indicates that some surgery was probably performed in the acute phase. Osteological data also supports that the wounds were kept clean, preventing severe infections that could be fatal if protruding the blood-brain barrier protection.

The individual at Östra Torp 4 was above average in height and was robustly built. It is probable that he was an important individual for the group in terms of economic contribution, but also as a protector or aggressor, prior to injury. It is probable that the individual was in need of help in order to remain a functional part of the society. This could have included changes in activities towards chores close to the settlement that did not demand handling several sequences following each other or fine motor skills. The individual was buried in accordance with other male burials associated with the Battle Axe culture. He did not receive a battle axe as grave goods, however. It is probable that this absence reflects that the individual was not a warrior. However, considering the neat fit between the traumas and the battle axe, it is probable that he was involved in violent activities prior to trauma – perhaps as a warrior or raider. However, regardless of the presence or absence of trauma, not all males were entitled to such a prestigious gift for their last rest, and this absence might have no correlation with the long-term problems associated with the traumatic brain injury. Olausson shows that the battle axe could only be associated with one burial where sex was osteologically determined – a male (Olausson, 2015, p. 102). It seems clear that trauma could be treated and managed in Neolithic societies, both short term and long term, and that there seems to have been no stigma associated with the physiological and cognitive problems generated by the traumatic brain injury. Considering the high prevalence of skull trauma, these kinds of problems might have been common and considered relatively unproblematic within the society. Accordingly, available care, both short term and long term, was probably also a matter of social survival. In a population where all individuals have an important role to fill in terms of providing nutrition or protection, it would be difficult to encourage this kind of provision if there was no guarantee for care when care was needed. The social unity is thus strengthened and maintained through this kind of caregiving. One can thus speak of a socially sustainable society (Missimer, 2015).

Paleopathological analyses of physical stress, high stature, and the possibility to survive for a long time after suffering from severe skull trauma all indicate that the LN–EBA society was relatively favourable in terms of health, at least in regards of nutrition, sanitation, and infectious disease. However, the labour

was hard, which is mirrored by the many degenerative changes on joints and spines that have been noted throughout this thesis, but which have not yet been published in separate articles, and are thus left only as this one note in the thesis synthesis (Swedish: kappa). Further, it is questionable whether it is possible to speak of a healthy population when somewhere between 10–20% of all individuals suffered from skull trauma, and as a result, sometimes life-lasting brain injuries. It all comes down to the definition of health.

### 6.3. Paleodemography and the formation of Bronze Age society

The difficulty of assessing old individuals through osteological methods has long been a problem. A general conclusion has been that reaching the ages of 70 and 80 is a modern phenomenon (Burger et al., 2012) and was not achieved in prehistoric societies. Paleodemographic analysis within this thesis has shown that this was not the case. When using transition analysis (Boldsen et al., 2002) the sample is aged in reference to an earlier population already in the registration phase (made in an ADBOU database) which excludes the problem of age mimicry related to traditional osteological aging methods. When applying this method on the LN–EBA sample of south Sweden, it is evident that the majority of deaths actually occurred between the ages of 70–80 (Paper IV).

Wood et al. (2002) ask how we could possibly provide detailed demographics for ancient populations if it is difficult to prove a detailed demographic analysis from the data on living ones. Therefore, they instead suggest working with demographical modelling so that an overview of the demographic profiles of ancient populations can be provided. This is also what I have done by using the Siler competing hazard model.

The results of the Siler modelling show that there is an elevated risk of dying in adolescence or as a young adult in the LN–EBA (Paper IV). This risk is significantly lower in the comparative populations. This elevated rate of mortality in the young years is plausibly an effect of complications surrounding childbirth and probably also violence (as well as accidents and sickness, of course), especially considering the high prevalence of violence-related trauma reported from Neolithic Denmark and Sweden (for reference see section 6.2. above).

Although there is much in the archaeological record to suggest a population increase in LN southern Sweden, including an increasing number of radiocarbon-dated skeletons which culminate in the EBA (see Appendix 2), this is not as easily detectable in the demographic analysis of the whole population. However, viewing only the results from the gallery grave Falköping stad 5 in Falbygden in southwestern Sweden, the Siler model shows possible evidence of population increase since as much as one-third of the material is comprised of children (Paper III). This is suggested as representative of normal rates of prehistoric child mortality according to Lewis (2007). The elevated risk of dying as an older child in the overall LN–EBA population might also be indicative of population increase. The gallery grave of Falköping stad 5 has been in use for a relatively short span in the LN I or early LN II with a second phase with three inhumations in the late LN II. When simulated to correspond to 1000 deaths, the Falköping stad 5 displayed a relatively high child- and subadult-mortality rate. The area of Falbygden is rather small, approximately 50km × 30km, and is well known for its large concentration of megaliths of different kinds (n=497), dating to both the MN and the LN (Persson and Sjögren, 2001, p.6). Weiler (1994) also argues that, considering the large number of stray finds, the distribution of gallery graves mirrors the actual settlement areas. It is possible that this small area was populated densely enough for infections to spread and sustain, causing high rates of juvenile mortality.

This seems not to have been the case regarding the LN–EBA population as a whole. The mortality profile shows the lowest rate of child mortality among all of the modelled populations, indicative of a low population pressure which is thus unable to sustain infections for any lengthy amount of time—the primal cause of mortality among children (Black et al., 2008; Roberts and Manchester, 2005).

Ahlström (2015) questioned the assumption that all skeletal assemblages pre-dating the industrial revolution, which do not comprise one-third children, are biased by taphonomic loss. Considering that it takes a population of approximately 250000–300000 individuals to be able to sustain infections (Bartlett, 1960), it is unlikely that this was a problem in Neolithic and EBA southern Sweden. That such high rates of child mortality should not be seen as a necessity is further strengthened by the mortality profile of the sparsely populated Junsele parish. In this population, only 10% of the children died within their first year and 20% within five years (Paper IV). It is evident that all densely populated sites under study display higher child- mortality rates

than those which are less densely populated. Low frequencies of juvenile bones in skeletal assemblages are thus not necessarily biased by taphonomic loss but could rather correctly reflect low population density. It is, of course, difficult to compare modern or early modern populations with prehistoric ones, since the total population is much higher in the late part. However, at present, it is impossible to compare the south Swedish LN–EBA sample to other prehistoric populations since the methods for age estimations differ and previous studies fail to find the highest ages because of methodological biases. Further studies of prehistoric demography are therefore necessary.

## 6.4. Social relations and socio-economic differences

The analyses of trauma and care show that it was possible to maintain a role within late MN society even with neurophysiological and neuropsychological disabilities. New functions for the injured in the society were probably allowed and arranged for by the others. Care in the acute phase also seems to have been advanced, indicating a system was available for medical treatment. Despite the traditional thought of the Battle Axe culture society as individualistic, this rather suggests that these individuals lived within a strong collective.

In regards of burial practice, there are no obvious differences between the Battle Axe culture and the first part of the LN (Paper I). The artefacts found in the graves are different but much of the burial tradition is similar, although not following the same strict scheme as before. The tradition of burials under flat earth remains throughout the LN and into the EBA, although is most frequent in the LN I. The individuals are buried both in crouching position, as is common in the Battle Axe culture, and in outstretched position on their backs. Most graves comprise one or two inhumations. This is somewhat different to the burials dated to the later part of the LN, when several inhumations in one grave becomes a more common practice. Flat burials dated to the Bronze Age are not as common and usually comprise only one inhumation. In this research, I have not encountered any skeletons dated to the LN I that were not from flat burials. However, there could be LN I reburials in MN passage graves that have not been included in this thesis considering the dating problems. There seems to be a lack of LN II inhumations in the material from Scania. Since the tradition of burying the dead in gallery graves continues throughout the EBA, it is possible that

earlier LN II burials were cleaned out and are therefore lost. A majority of the radiocarbon-dated skeletons from Scanian gallery graves are of Bronze Age date (Paper I). About half of the individuals dated to the LN II were inhumed in gallery graves and flat earth graves respectively. It is probable that the real number of LN II inhumations in Scanian gallery graves was substantially higher, which can be seen in the gallery graves of Västergötland where the tradition of Bronze Age reburials in gallery graves is not as common (Blank, 2015). I argue that the increased diversity in burial tradition is related to an increase in social stratification in the LN II, culminating in the EBA. The custom of Bronze Age burials in Scanian gallery graves is interpreted as the burials of 'commoners' by Bergerbrant et al. (2017) and by me. As Holst et al. (2013) estimate the proportion of the population that were buried in barrows as 20%, a majority of Bronze Age burials were missing. These burials have now been found through direct radiocarbon dates on skeletons, showing the importance of large quantities of radiocarbon dates.

The gallery grave as the last resting place for Bronze Age commoners is further supported by the observation that there are fewer burial goods related to individuals in gallery graves than in other grave forms (Stensköld, 2004, p.136). Furthermore, Inger Håkansson (1985) suggests that there is a hierarchy among burial types where the central grave in barrows is the most prominent, followed by other burials in barrows, flat earth graves and, lastly, gallery graves. There are a number of features that indicate increased social stratification beginning in the LN. Apel (2001) interprets the manufacturing and distribution of high-quality flint daggers as signs of specialization and control of production and distribution. Beginning already around 2300 BCE, there is an increase in the variation of house architecture throughout the LN, culminating in the EBA (Artursson, 2005; Kristiansen, 2006). Kristiansen interprets the large houses as houses for the elite where there were living areas in the west and a byre in the east. This type of storage (e.g. stalling the stock) would signal a new form of ownership and control over the production (Kristiansen, 2006). In Scania, small hamlets are also developing during the LN (Brink, 2013) which are situated where flint is abundant, whereas only scattered houses are present where flint resources are scarce. This is a plausible indication of a centre-periphery associated with social stratification (Artursson, 2005; Brink, 2013). These villages also correlate with an intensified and more stable agro-pastoral economy during this time (Prescott 2009). Although there seems to have been some sort of stratified society already during the LN, Kristiansen and Earle point out that there is a large difference between this society and the one seen in the Bronze Age, where

the political power is based on permanent organization that allows for long-distance international trade with a few core areas (Kristiansen and Earle, 2015). On this I agree; there is a difference in the organization and extent of organized political power between the LN and the EBA. However, I argue that it is the development in the LN that allows for this new political organization and that initial social stratification and political organization is present already during this time. Iversen (2017) acknowledges, as do I in Paper I, that there is a clear division of the LN I and LN II somewhere around 2000 BCE, and he refers to the LN II–EBA Ia as a transitional phase or a proto-Bronze Age. Furthermore, Iversen (2017) argues that although the fully developed Bronze Age starts around 1600 BCE, this development had been accelerating without possible return already from 2000 BCE. I fully agree in this interpretation and this is also reflected in the increase in burial complexity in Scania from 2000 BCE onwards.

Cattle were probably of significant importance and value for the population's survival and for trade during the LN. There is evidence for a high mobility among cattle in Falbygden already during the MN, where more than 50% of the teeth analysed for strontium isotopes (n=21) showed non-local origin. The frequency for sheep is not as high (Sjögren and Price, 2013). It is possible that this is reflective of cattle trade already being present in the MN in Falbygden.

Among the pastoralists of the Nuer, a rich man is the man who owns several cows in lactation period, since this provides nutrition for the family all year round, even when the millet (that is considered the second primary nutrition base) runs out before the next harvest season (Evans-Pritchard, 1937). The milk among the Nuer was also shared to those in the village without cows in the lactation period. In Falbygden there is direct evidence of milk or dairy products from cattle in at least half, but most probably all, of sampled individuals (n=6) (Fotakis et al., forthcoming.). Dairy could be stored and continuous milking would provide nutrition all year round and would eventually generate a surplus. Evidence of dairy has also been found in a storage vessel in Kyrsta, central Sweden. The food residues were <sup>14</sup>C dated to the LN–EBA I (Ua-24519). The porous material of the vessel was ideal for keeping liquids cold (Onsten-Molander and Wikborg, 2006, p. 155f). The generated surplus could be traded. Further consequences of the Secondary Products Revolution would include higher nutrition and more arable land availability, which would allow for a further population increase, all triggers for a Bronze Age society (Earle, 1989). This kinds of continuous surplus

production would eventually lead to social inequality (Hayden, 1995, p. 21). However, power could only be upheld and supported if it was also beneficial for the commoners. For example, feasting in this kind of society is only held when there is a surplus, never when there are nutritional strains (Hayden, 1995, p. 22). In this sense, one can say that abundance equals power (Hayden, 1995, p. 23). This fact might explain why there are no obvious differences in health status detectable in the LN–Bronze Age material in south Sweden, although there are indications of decreased stature among females in the later parts. This decrease in female statures could also be linked to the fact that adult women were moving in to southern Sweden through, for example, marriage arrangements, to a higher degree than before. The analyses of stable isotopes in LN II–EBA skeletons from Scania further suggest that there was no difference in diet between burial types (e.g. different social strata). There is a difference in the rate of dental caries between individuals buried in gallery graves and barrows which might indicate a somewhat different diet among the elite, but this difference was not statistically significant ( $p=0.0818$ ) and might also plausibly be the result of luxury foods not being able to be targeted in stable isotope analysis. Although analyses of stable isotopes is a powerful tool for reconstructing diets in the past, analyses of dental caries and dental calculus might be a better method for detecting small differences in dietary habits and cuisine.

## 6.5. The biocultural bioarchaeology of affluence and political-economy

To sum up the major findings and contributions of this thesis, I would like to consider all of the aims discussed above and highlight in what way the bioculturally oriented bioarchaeology of affluence and political-economy has changed and strengthened traditional archaeological understandings of the LN and the development of the Bronze Age in southern Sweden. Through bioarchaeological theories and methods I have provided new knowledge that is undetectable through material culture in the traditional sense. Bioarchaeological studies of changes in political-economy and differences in social status require a wide perspective and an inclusion of interrelated skeletal responses. This has been done in this thesis.

I have also analysed the biological response to the Secondary Products Revolution and affluence, and the biological responses to social and economic inequality in different ways in the five papers.

Intensification in agricultural production and, as a result, nutrition, was both beneficial and disadvantageous on human health as reflected in skeletal responses. The increase in dental caries shows the negative effects of intensification in cereal production following manuring and use of primitive ploughs. The large cavities that were occasionally present make one reflect over the horrible pain these individuals must have suffered from. These cavities also increased the risk of blood poisoning. The low–moderate frequencies of degenerative responses to stress, such as cribra orbitalia and enamel hypoplasia, together with the statistically significant increase in stature in the Battle Axe culture are, however, distinct pieces of evidence in support of sufficient nutrition and good general health. I argue that this is a direct effect of affluence related to increased access to nutrition following an intensified use of secondary products. A good chance of accessing nutrition and possibilities of care would also enable survival into older ages, as was visible in the paleodemographic analyses.

However, there are also some signs of social inequality, at least in the LN II–EBA. One of the major findings is that a majority of the inhumations in gallery graves are from the EBA and not the LN. Burial diversity increases throughout the Neolithic and culminates in the Bronze Age. I believe that this is a reflection of an increase in social inequality. This is further supported by the fact that there are differences in rates of dental caries between probable elite burials in mounds and common burials in gallery graves which might relate to honey-sweetened luxury foods. These differences are not, however, statistically significant ( $p=0.0818$ ). However, the decrease in female stature in the LN II–EBA is also a possible sign of increased social differences that might have affected the amount of nutrition and general health, thus leading to decreased statures. Only one of the female individuals from this time period is buried in a mound grave which means that individuals who were buried in low-status graves have a more significant contribution to mean stature. The frequency of enamel hypoplasia is also higher in the gallery grave of Falköping stad 5 than in the mound burials of Abbekås (Tornberg, 2013). This might also mirror differences in social status of the inhumed in the two different burial types, but it cannot be ascertained.

There is an increased mobility in the Falbygden area in the LN compared to the MN. It is possible that this is related to increased trade or generally better

opportunities for mobility, perhaps because of the introduction of the horse. It is probable that the horse was introduced in southern Scandinavia during the Battle Axe culture.

The Bronze Age is also associated with warrior elites. It is possible that a high amount of violence in LN–EBA society contributed to a relatively high age non-specific mortality visible in demographic data. Age non-specific mortality is all mortality that is not connected to the initial high child mortality or connected to senescence. It seems, however, as if population density remained relatively low in the LN–EBA considering the low rates of child mortality. This is somewhat contradicted by mortality profiles from Falköping stad 5, where child- and juvenile-mortality rates are higher. The Falbygden area is relatively small but still contains a large number of megaliths. It is possible that the population density in this small area was high enough for infections to be sustained, thus affecting child mortality negatively.



# 7. Conclusions

It is evident that burial complexity increases from the early part of the LN to the EBA. New radiocarbon dates on individuals in graves that have previously only been typologically dated show that there were many burial traditions simultaneously in the province of Scania, especially during the EBA. It is concluded that gallery graves were constructed after 2000 BCE and used for a long period of time, at least into the EBA. The majority of the radiocarbon dates of gallery graves suggest Bronze Age burials. The diversity in burial practice is interpreted as coinciding with an increase in social diversity and a more politically and economically diverse society where visible differences between the “elite” and “commoners” become important to uphold power.

An Analysis of Variance (ANOVA) showed that there is no significant difference in diet associated with burial tradition, at least not one that is detectable through stable isotopes. There are, however, some differences in the rates of dental caries between the burial types, the difference between gallery graves and barrows being the largest, although this difference is not statistically significant. It is possible that traditional assumptions about high levels of meat consumption among the “elite” are not valid during the LN and EBA. High values of  $\delta^{15}\text{N}$ , however, imply that manuring was practiced in Scania during the LN and EBA.

This thesis has also provided new, valuable information about stature changes in the Neolithic and Bronze Age. Although dependent on both the environment and genetics, stature might better reflect general health in past populations. The analyses within this thesis show that there is no difference in stature associated to the Neolithic transition that could be indicative of health changes following this event. There is, however, a significant increase in male stature associated to the Battle Axe culture that then remains high throughout the LN and EBA. It is probable that there are multiple parameters that support this increase, including higher genetic variation depending on population increase and possible immigration, and better nutrition and health. Female stature seems to increase more evenly throughout the Neolithic but

decreases in the LN II–EBA. It is possible that this is reflective of a negative health change for females during this period.

There is evidence of agro-pastoral intensification in the bioarchaeological and archaeological record that probably also corresponds to an increased reliance on secondary products. Raw data of stable isotopes  $\delta^{15}\text{N}$  are lower in the LN Falbygden and Scania in relation to the MN in Falbygden. This might reflect a higher reliance on cattle over pigs, which is also suggested by the zooarchaeological record. However, there are overlaps between MN and LN samples, and the difference does not correspond to a whole trophic level. Through analyses of ancient protein preserved in dental calculus from the gallery grave Falköping stad 5, a parallel project has also found evidence of cow's-milk consumption in at least three, but possibly six, out of six sampled individuals.

The collagen-apatite spacing in the gallery grave Falköping stad 5 is  $6.3\pm 0.9$  which is more consistent with a herbivorous diet than a carnivorous one. An increased reliance on carbohydrates is also suggested by a clear increase in dental caries between farmers of the MN and farmers of the LN and EBA in Scania and Falbygden.

The variation in  $\delta^{15}\text{N}$  values in LN–EBA Scania and LN Falköping stad 5 is higher than in the MN period, which has also previously been confirmed in other studies in Falbygden. It is possible that this is dependent on differences in manuring between groups in the LN–EBA according to economic factors. This increase in variation would thus mirror an increase in political-economic differences in the LN–EBA in both areas.

Reliable sources of nutrition and low risk of infections are probable explanations for the absence of cribra orbitalia and the low amount of severe enamel hypoplasia in the LN. Although a relatively high percentage of the individuals in Falköping stad 5 showed signs of enamel hypoplasia, most of them were only affected on the canines and a majority lived into adulthood. Enamel hypoplasia of the canine is common and is thought to be a poor indicator of bad general health but is, rather, reflective of teeth crowding or local nutrition deficiencies.

Although much of the archaeological evidence points to a population increase in the LN, the paleodemographic modelling suggests that the population density was relatively low. Low rates of child mortality are interpreted as primarily being due to low risk of infectious disease, not taphonomic loss. In comparison with early modern samples, the demography of LN–EBA

southern Sweden most closely resembles that of the rural Junsele parish in northern Sweden. Age non-dependent mortality in the LN–EBA is, however, much higher than the comparative populations. This might reflect the lack of modern medicine in relation to child birth, as well as probable higher rates of violence.

The demographic profile of LN–EBA south Sweden points to a Bronze Age society with relatively low population density and relatively lower subadult-mortality rates compared to prehistoric proto-cities. Although there are signs of increased social differentiation already in the LN, the kind of social stratification characterizing Bronze Age societies could not be found until at least the EBA II. There is an increase in burial diversity throughout the LN that culminates in the Bronze Age. This heterogeneity might reflect an increasing social stratification. A majority of burials in gallery graves are dated to the EBA, and not the LN as presumed. Since only 20% of the total Bronze Age population is thought to have been privileged with a barrow burial, it is likely that Bronze Age burials in gallery graves are those of commoners. I have not been able to conclude that there are differences in diet and health between the different burials that could further support this division; however, differences in the frequencies of dental caries, although not statistically different, might reflect a somewhat different cuisine among elites buried in barrows than of commoners buried in gallery graves.

An earlier study has shown a relatively high frequency of skull trauma in Neolithic Denmark and Sweden. Most of these traumas showed signs of healing and many of them were substantial and probably connected to traumatic brain injury. In my thesis, an individual with two severe skull traumas was evaluated for possible traumatic brain injury with reference to modern medicine. It is probable that this individual would have suffered from initial unconsciousness and problems with motor skills. Problems with fine motor skills probably continued in the long term and the individual would have had long-term problems with spatial orientation and sequences in complex activities. The individual would have needed care and support from his surrounding citizens, both in the acute phase, where primitive surgery, possible use of antiseptics, and help with rudimentary activities were provided, and in the long term, where help with orientation and activities that are constructed of several sequences (such as flint knapping) was available. This suggests that it was possible to be a functional part of Neolithic society even with severe traumatic brain injury, probably through a tight collective.



## 8. Archaeological implications in south Swedish archaeology and future research

The LN and EBA have finally recovered their ‘commoners’. The application of bioarchaeology in this quest, especially through a large number of radiocarbon dates, has proven fruitful. This discovery has also made it possible to provide evidence of probable differences in dietary habits possibly linked to consumption of luxury foods among the elite. However, the increase in political and economic differences across the populations might have resulted in worsened health among the ‘commoners’ in the EBA. Considering an increase in mobility and dietary variability, it is possible that a more specialized society was already present, at least by LN II. Considering the long-term survival of an individual from the Battle Axe culture with severe skull trauma, it is evident that both medical knowledge and care giving on a number of different levels were available in these societies. Such practices would have been a necessity in order to be able to sustain a population affected by a relatively high rate of violence.

Preceding the period of political and economic inequalities was, however, a period of apparent affluence, which is reflected mainly by high statures. The previous scholarly understanding has been that stature increases in the LN. However, the radiocarbon dates of a large proportion of skeletons sampled from a lengthy span of time have shown that a large stature increase is instead related to the Battle Axe culture, which then remains throughout the Neolithic and into the EBA. There are also close resemblances in burial traditions between the Battle Axe culture and LN I (Paper I) and I question whether there is good reason not to include the Battle Axe culture in the LN instead of the MN. Considering this, the increased reliance on secondary products might also be placed in this period. This question could also be raised when considering the relationship between the LN II and EBA I, as has been asked previously in some debates. I would say that there is a primitive

form of a Bronze Age society already in existence during the LN II that was not fully developed until the EBA II. Accordingly, an inclusion of the LN II into the Bronze Age would be preferable. However, the results of the paleodemographic analyses provide evidence that southern Sweden was sparsely populated during the LN–EBA and could probably not be compared to Bronze Age cities of southern Europe. This population density was probably not present in Sweden until modern times. However, the small area of Falbygden might be an exception. Very large numbers of megalithic tombs dating to the MN and LN provide evidence of significant human activity in the area. The paleodemographic analysis of the gallery grave in Falköping stad 5 shows higher rates of child mortality in Falköping stad 5 than in the overall population which might be indicative of the area of Falbygden having a population density large enough for infectious diseases to be sustained. Paleodemographic analyses based on modern age-estimation techniques would allow for further understanding of living and dying in Bronze Age societies to be possible. This would also make it possible to further evaluate whether low frequencies of children in prehistoric skeletal assemblages reflects high rates of taphonomic loss or low population density.

Although this thesis has provided many answers to long-discussed archaeological questions, a few new questions have arisen as a result of this thesis. The first question concerns the extent to which violence was present during the Bronze Age, and the extent to which there was survival. This is interesting in relation to discussions of warrior elites in the Bronze Age. It would also be interesting to compare trauma frequencies between the LN and EBA, as well as between supposed elites and ‘commoners’. This project will be undertaken during the summer of 2018 with grants from the Anders Althin’s Foundation. Comparisons to the Danish material and Central European materials would also be of interest in a later stage.

The biological (skeletal) response to nutrition and health has been evaluated and discussed through the lenses of a bioculturally oriented bioarchaeology. In the future it would be interesting to follow Leatherman and Goodman’s advice to be “paying more attention to the costs of adaptations and ultimately how consequences and responses to stress shape future environments and behaviors” (Leatherman and Goodman, 1997, p. 2). In a LN–EBA setting this could correspond to a consideration of the societal consequences which might result from increases in levels of social inequality: a higher mortality rate among parts of the population, risk of overexploitations of resources, etc. There seems to have been a change in agricultural practice in the LBA

(Harding, 1989). Some scholars argue for a decline in population and resources during the LBA because of over-exploitation of soils (Earle, 2002, p. 318 ff). If this is true, it is possible that this is codependent on the biocultural adaptations in the LN–EBA and is an effect of population increase, worsened population health, and the over-burdening of resources.

Lastly, but perhaps of the greatest importance, is the bioculturally oriented bioarchaeology in relation to results from analyses of ancient aDNA. Ancient DNA has a fantastic potential for studying many aspects of diseases, as well as migration. However, at present, samples are often small and the DNA preservation is not always sufficient which makes these kinds of studies sensitive to overgeneralizations. It is also important not to equate genes with culture. The foundation of archaeological research is the expression of culture. I argue that bioculturally oriented bioarchaeology has an important part to play as the counterweight to aDNA research. Bioarchaeology has the opportunity to generate new knowledge about the codependence of human biological adaptation or stress to these cultures and, likewise, to contribute to the knowledge of new cultural expressions caused by these biological adaptations. Here, also, aDNA has a role; just one example would be regarding the ability to digest milk sugar in adulthood. However, in accordance with the view of Heyd (2017), I believe that it is important not to become blinded by all of this new genetic information, but to evaluate these results as parts of a puzzle that, together with biocultural and other archaeological theories, can generate new understanding of the past.



## 9. Svensk sammanfattning (Swedish Summary)

I den här avhandlingen har jag undersökt diet och hälsa under senneolitikum och äldre bronsålder i södra Sverige. Studien är bioarkeologisk och baseras främst på studier av människoskelett. Bioarkeologin som disciplin har sin grund i antagandet att människans biologi och människans kulturella beteende är starkt sammankopplade och beroende av varandra. Kulturen påverkar människans biologi, t ex genom att ett ökat fokus på jordbruk ger högre andel karies, och människans biologi påverkar också kulturen, t ex att en viss typ av genmutation gör att människan kan dricka mjölk även i vuxen ålder. På grund av detta kan vi genom att studera människors skelett också berätta något om de kulturella praktiker som människorna hade och det samhälle som hon levde i.

De flesta arkeologer är överens om att samhället blev mer stratifierat under bronsåldern än vad det hade varit under neolitikum. Anledningen till den ökade stratifieringen kan antingen härledas till distributionen av metall eller till en intensifiering i jordbruket vilket ledde till ett ekonomiskt överskott hos en del av befolkningen. Grunden till detta ligger i senneolitikum. Både en intensifiering av jordbruket och socio-ekonomisk olikhet påverkar troligtvis dieten och hälsan hos befolkningen, vilket kan studeras genom ett bioarkeologiskt angreppssätt men är osynligt i övrigt arkeologiskt källmaterial. Eftersom studiet görs av biologiska lämningar av de människor som en gång levde finns också möjlighet att studera de olika samhällsskikten under likadana förutsättningar. På så sätt kan bioarkeologin bidra till helt ny och unik kunskap om människors livsvillkor under senneolitikum och äldre bronsålder.

Syftena med den här avhandlingen är att

- i.) utvärdera diet, näringsfång och eventuella skillnader i diet i senneolitikum och äldre bronsålder.
- ii.) med ett holistiskt förhållningssätt ge belägg för hälsa, förändringar i hälsa samt omvårdnad under neolitikum och äldre bronsålder.
- iii.) genom statistisk modellering få fram en demografisk profil för senneolitikum och äldre bronsålder i södra Sverige.
- iv.) analysera sociala relationer genom bioarkeologiska metoder.

Syftena utforskas genom de studier som publicerats i form av fem olika artiklar. Varje artikel belyser en eller flera frågor som ligger till grund för att uppnå målsättningarna för den här avhandlingen.

Det skelettmaterial som ligger till grund för studierna kommer från 46 olika lokaler i Skåne, Västergötland, Östergötland, Närke och Uppland. Majoriteten av materialet kommer från Skåne. Skeletten har analyserats osteologiskt och biokemiskt i form av isotopanalyser för att diskutera diet och mobilitet. Utöver detta baseras studierna också på en större mängd  $^{14}\text{C}$ -dateringar av skelettmaterialet.

Att använda sig av en stor  $^{14}\text{C}$ -dateringar kan bidra till helt ny kunskap. I Paper I visar jag hur de  $^{14}\text{C}$ -dateringar som jag har gjort inom ramen för den här avhandlingen visar att majoriteten av de skelett som återfinns i senneolitiska hällkistor är begravda under äldre bronsålder och inte senneolitikum. Användandet av hällkistor har alltså fortgått i mycket högre utsträckning än vad som tidigare var känt. Genom dateringarna kunde jag också påvisa att det finns en ökad spridning i gravskick från den tidigaste delen av senneolitikum in i äldre bronsålder, då flest typer av gravskick finns dokumenterade. Jag menar att det här fenomenet är relaterat till en ökad skillnad också i social stratifiering vilket kulminerar i äldre bronsålder. De monumentala högbegravningarna under äldre bronsålder innehåller gravar ämnade för en individ som ofta fått med sig fina gravgåvor i form av bronser. I hällkistorna delar flera individer samma grav vilket gör den kollektiv och inte personlig. Hällkistorna innehåller också mycket få bronser och de bronser som återfinns är små och oftast tillhörande klädedräkten. Jag kunde däremot inte genom isotopanalyser påvisa att det fanns skillnader i dieten mellan människorna i de olika typerna av gravar. Analyser av karies visar att det kan finnas skillnader i frekvens mellan de olika gravarna, men den här skillnaden kan inte säkerställas statistiskt. Kariesfrekvensen i gravhögar är

något högre än kariesfrekvensen i hållkistor. Individer som begravts i gravar under flat mark har kariesfrekvenser som ligger mitt emellan hög- och hållkistbegravningar. Det är möjligt att detta reflekterar en något skild diet mellan individerna beroende av politiska och ekonomiska skillnader.

Jag menar att de sociala skillnaderna som vi kan skönja under bronsålder har sin grund i en agro-pastoral intensifiering under den senaste delen av stenåldern. En agro-pastoral intensifiering skulle bidra till en ökad tillgång på näring, vilket skulle möjliggöra befolkningstillväxt och mindre utsatthet för bristsjukdomar. Det skulle dock även innebära en ökad risk för karies när en större mängd spannmål bidrar till dieten och även en större risk för infektionssjukdomar när människorna lever mer trångbott. En agro-pastoral intensifiering skulle också bidra till ett ökat ekonomiskt överskott hos vissa, vilket ligger till grund för en ökad social stratifiering. Genom att studera diet, hälsa och demografi hos individer från neolitikum och bronsålder kan man också berätta mycket om den politisk-ekonomiska situationen. Inom ramen för avhandlingen har jag därför studerat kroppslängd, sjukliga förändringar i skeletten, diet och demografi. Kroppslängd är starkt förknippat med goda levnadsförhållanden. Tillsammans med ett stort antal  $^{14}\text{C}$ -analyser kunde jag i Paper II påvisa att det skedde en stor ökning i mäns kroppslängd mellan den tidigare delen av neolitikum och den senare delen av neolitikum i övergången till det vi kallar Stridsyxekultur (c. 2800-2300 f.Kr.). De manliga kroppslängderna förblev sedan höga in i äldre bronsålder. Studien visar också att den första övergången till jordbruk endast påverkade kroppslängderna marginellt. De kvinnliga kroppslängderna ökade mer linjärt från senmesolitikum till äldre delen av senneolitikum när de var som högst. De tenderar sedan att minska i äldre bronsålder. Det är möjligt att den här kroppslängdsminskningen hör samman med sämre näring och en sämre hälsa hos kvinnor under äldre bronsålder. Alla utom ett av de kvinnliga skeletten daterade till äldre bronsålder kom också från gravar som kan tolkas tillhöra ett lägre samhällskikt. Den markanta ökningen av manliga kroppslängder under Stridsyxekultur har förmodligen att göra med flera faktorer, så som ökad invandring och således en större genetisk heterogenitet och ökad näringstillgång som ledde till bättre hälsa.

För att ta reda på mer om diet, sjukdomar och demografi under senneolitikum gjorde jag tillsammans med Malou Blank och Corina Knipper en studie av skeletten från en hållkista i Falköping (Paper III). Vi analyserade skeletten med en stor variation av arkeologiska, biokemiska och osteologiska metoder och kunde konstatera att hållkistan använts under en relativt kort period på

ungefär 100 år. Eventuellt har hällkistan använts i två separata omgångar där den senare delen representeras av endast tre individer. Samtliga av dessa individer tycks också ursprungligen komma från ett område utanför Falbygden. Strontiumisotoper visar på att majoriteten av de gravlagda inte kommer från det geografiska området Falbygden. Några kan ha sitt ursprung från området alldeles utanför Falbygden, men ett flertal måste också komma längre bort ifrån. Stabila isotoper visar också att människorna begravda i hällkistan förmodligen har haft en diet baserat på en högre andel vegetabilier och kanske mer nötkött eller mjölk än svinkött, än vad människorna i samma område hade under mellanneolitikum. Skeletten visade på fåtal tecken på näringsbrist och hade också kroppslängder motsvarande den övriga befolkningen i Sydsverige. Demografiska analyser visar att det fanns en ganska stor risk att avlida redan som ung vuxen och att barnadödligheten var högre i Falköping stad 5 än vad den var i Sydsverige i stort under den här tiden. Den största anledningen till att spädbarn dör i världen idag är att de drabbas av svåra infektioner. Genom jämförelser med olika populationer har jag kunnat visa på en stor likhet i överlevnad hos människorna under sydsvensk senneolitikum-äldre bronsålder och människor som levde i Junsele under 1700-talet (Paper IV). Det fanns också möjlighet att leva till åldrar uppåt 80 år. För att infektioner ska kunna spridas och upprätthållas krävs en relativt hög befolkningstäthet. En sådan hög befolkningstäthet har förmodligen inte funnits i södra Sverige under senneolitikum-äldre bronsålder och har inte heller funnits i Junsele under 1700-tal. Det är därför troligt att den låga andel barnskelett som återfinns i förhistoriska kontexter snarare är en indikation på låg befolkningstäthet och en faktisk reflektion av låg barnadödlighet och inte en enbart stor tafonomisk förlust, vilket ofta brukar argumenteras för. De demografiska analyserna tyder dock på att just området kring Falköping hade en högre befolkningstäthet än resten av Sydsverige vilket ökade risken för infektioner.

Paper V är något annorlunda än de övriga artiklarna. Dels baseras studien på en enda individ och dels är skelettet daterat till Stridsyxekultur. Artikeln är skriven tillsammans med Lars Jacobsson. Studien berör omvårdnad och komplikationer efter två svåra skalltrauman med trolig hjärnskada. Placeringen av skalltraumana indikerar att individen, som är en man, via sin hjärnskada har haft problem med motorik, inlärning och spatial orientering. Individen har behövt omvårdnad både i det akuta skedet och fortsättningsvis lång tid efter traumat för att kunna fungera i vardagen. I det akuta skedet har individen behövt hjälp med rudimentära sysslor så som hygien, men också såromläggning, födoinhämtning och att se till att undvika infektioner. Denna

omvårdnad har kunnat upprätthållas. I det längre perspektivet har individen framförallt behövt stöttning i att hitta och kanske genom att få ansvar för andra sysslor än vad han tidigare har haft. Det finns inget i skelettet som tyder på att individen har haft långvariga problem med motoriken. Det står klart att omvårdnad existerade som en viktig del i det neolitiska samhället och var förmodligen nödvändig då skalltrauman inte var särskilt ovanliga och därför krävdes för att samhället skulle kunna vara socialt hållbart.

De analyser som har utförts inom ramen för den här avhandlingen pekar på en intensifiering i jordbruket under senneolitikum vilket resulterade i höga kroppslängder, ökad mängd karies och en relativt låg risk för infektionssjukdomar. Studierna visar också på att, trots att det finns många arkeologiska belegg för en populationsökning under senneolitikum och äldre bronsålder så levde människor ändå så pass glest att det inte fanns någon större risk för långvariga infektioner. Ett undantag kan vara området kring Falbygden där spädbarnsdödligheten är högre än i Sydsverige i stort. Området kring Falbygden är känt för sina många megalitgravar från mellan- och senneolitikum vilket kan reflektera att människor levde tätare här än i andra delar av Sydsverige. Det tycks också ske en förändring i diet i senneolitikum där ett större fokus finns på spannmål och produkter från nötkreatur. Det är troligt att det här förlyttandet i fokus är relaterat till ett ökat nyttjande av sekundära produkter i form av mjölkprodukter och arbetskraft. Den ökade födotillgången har sedan resulterat i ökad handel och ökade sociala skillnader, vilket påvisas av en ökad mobilitet, ökade skillnader i begravningssätt och en minskning av kvinnliga kroppslängder under äldre bronsålder.



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# Appendix 1: Summary Tables

Abbreviations:

DJD=Degenerative Joint Disease

IVD=Intervertebral Disc Disease

OA=Osteoarthritis

OD=Osteochondritis Dissecans

ID	1
<b>Region</b>	Scania
<b>Parish</b>	Äspö
<b>Site name</b>	Äspö 16
<b>Raä no.</b>	n.a.
<b>Inventory no.</b>	LUHM 26981
<b>Year of excavation</b>	1932
<b>Excavator/-s</b>	B-M. Vifot
<b>Grave type</b>	Gallery Grave
<b>MNI</b>	4
<b>No. Adults</b>	4
<b>No. Juveniles</b>	0
<b>No. Males</b>	1
<b>No. Females</b>	1
<b><sup>14</sup>C analysis</b>	No
<b><sup>13</sup>C‰</b>	
<b><sup>15</sup>N‰</b>	
<b>Trauma</b>	
<b>Cribræ orbitalia</b>	
<b>Enamel hypoplasia</b>	1
<b>Dental caries</b>	8
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	1
<b>Pathology other</b>	Osteophytes on one sustentaculum tali and proximal MTIV, dexter. Marginal osteophytes on one lumbar vertebra.

<b>ID</b>	2
<b>Region</b>	Scania
<b>Parish</b>	Barsebäck
<b>Site name</b>	Rörbäck 10
<b>Raä no.</b>	Barsebäck 10:1
<b>Inventory no.</b>	LUHM 26967
<b>Year of excavation</b>	1932
<b>Excavator/s</b>	J. E. Forssander
<b>Grave type</b>	Cairn
<b>MNI</b>	3
<b>No. Adults</b>	3
<b>No. Juveniles</b>	0
<b>No. Males</b>	2
<b>No. Females</b>	1
<b><sup>14</sup>C analysis</b>	Yes
<b><sup>13</sup>C‰</b>	
<b><sup>15</sup>N‰</b>	
<b>Trauma</b>	
<b>Cribra orbitalia</b>	
<b>Enamel hypoplasia</b>	
<b>Dental caries</b>	4
<b>Schmorl's nodes</b>	
<b>OA</b>	1
<b>Periostitis</b>	
<b>Pathology other</b>	Grave 3: DJD in cervical vertebrae

**Comment:** Grave 1: Hip subluxation with OA on femoral head and acetabulum, sin.

<b>ID</b>	4
<b>Region</b>	Scania
<b>Parish</b>	Fosie
<b>Site name</b>	Tannhäuser
<b>Rää no.</b>	Fosie 15:1
<b>Inventory no.</b>	MHM 1247
<b>Year of excavation</b>	1966
<b>Excavator/s</b>	N-O. Nilsson
<b>Grave type</b>	Flat burial
<b>MNI</b>	1
<b>No. Adults</b>	1
<b>No. Juveniles</b>	0
<b>No. Males</b>	0
<b>No. Females</b>	1
<b><sup>14</sup>C analysis</b>	No
<b><sup>13</sup>C‰</b>	
<b><sup>15</sup>N‰</b>	
<b>Trauma</b>	
<b>Cribra orbitalia</b>	
<b>Enamel hypoplasia</b>	
<b>Dental caries</b>	
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	

<b>ID</b>	5
<b>Region</b>	Scania
<b>Parish</b>	Malmö
<b>Site name</b>	Höjagården
<b>Raä no.</b>	Västra Skrävlinge 3:1
<b>Inventory no.</b>	MHM 1264
<b>Year of excavation</b>	1966
<b>Excavator/s</b>	C. Wahlöö
<b>Grave type</b>	Barrow
<b>MNI</b>	2
<b>No. Adults</b>	1
<b>No. Juveniles</b>	1
<b>No. Males</b>	1
<b>No. Females</b>	
<b><sup>14</sup>C analysis</b>	No
<b><sup>13</sup>C‰</b>	
<b><sup>15</sup>N‰</b>	
<b>Trauma</b>	
<b>Cribra orbitalia</b>	1
<b>Enamel hypoplasia</b>	
<b>Dental caries</b>	
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	

<b>ID</b>	9
<b>Region</b>	Scania
<b>Parish</b>	Hököpinge
<b>Site name</b>	Vattenöverföringsledningen Hyllie, Vellinge
<b>Räa no.</b>	Hököpinge 34
<b>Inventory no.</b>	MHM 265
<b>Year of excavation</b>	2005
<b>Excavator/-s</b>	K. Gidlöf, A. Gruber
<b>Grave type</b>	Flat burial
<b>MNI</b>	1
<b>No. Adults</b>	1
<b>No. Juveniles</b>	0
<b>No. Males</b>	1
<b>No. Females</b>	
<b><sup>14</sup>C analysis</b>	No
<b><sup>13</sup>C‰</b>	
<b><sup>15</sup>N‰</b>	
<b>Trauma</b>	1
<b>Cribra orbitalia</b>	
<b>Enamel hypoplasia</b>	
<b>Dental caries</b>	4
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	1
<b>Pathology other</b>	

<b>ID</b>	11
<b>Region</b>	Scania
<b>Parish</b>	Skivarp
<b>Site name</b>	Abbekås, barrow 1
<b>Raä no.</b>	Skivarp 19:1; 19:2
<b>Inventory no.</b>	LUHM 20797
<b>Year of excavation</b>	1920-1923
<b>Excavator/-s</b>	F. Hansen
<b>Grave type</b>	Flat burial Gallery grave Barrow
<b>MNI</b>	13
<b>No. Adults</b>	11
<b>No. Juveniles</b>	2
<b>No. Males</b>	
<b>No. Females</b>	
<b><sup>14</sup>C analysis</b>	Yes
<b><sup>13</sup>C ‰(mean)</b>	-20.1±0.40 (n=7)
<b><sup>15</sup>N‰ (mean)</b>	9.66±0.55 (n=7)
<b>Trauma</b>	2
<b>Cribra orbitalia</b>	1
<b>Enamel hypoplasia</b>	15 (3)
<b>Dental caries</b>	5
<b>Schmorl's nodes</b>	2
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	IVD in several vertebrae (grave 4); maxillary sinusitis (grave 14); DJD in knees and left shoulder (grave 15)

**Comment:** () indicates number of individuals.

<b>ID</b>	13
<b>Region</b>	Scania
<b>Parish</b>	Skivarp
<b>Site name</b>	Abbekås, barrow 2
<b>Raä no.</b>	Skivarp 20
<b>Inventory no.</b>	LUHM 20918
<b>Year of excavation</b>	1920-1923
<b>Excavator/s</b>	F. Hansen
<b>Grave type</b>	Barrow
<b>MNI</b>	5
<b>No. Adults</b>	2
<b>No. Juveniles</b>	3
<b>No. Males</b>	
<b>No. Females</b>	1
<b><sup>14</sup>C analysis</b>	Yes
<b><sup>13</sup>C‰</b>	-19.3
<b><sup>15</sup>N‰</b>	10.5
<b>Trauma</b>	
<b>Cribra orbitalia</b>	
<b>Enamel hypoplasia</b>	
<b>Dental caries</b>	
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	

<b>ID</b>	14
<b>Region</b>	Scania
<b>Parish</b>	Vä
<b>Site name</b>	Ängamöllan
<b>Raä no.</b>	Vä 31:1
<b>Inventory no.</b>	LUHM 28771
<b>Year of excavation</b>	1945
<b>Excavator/-s</b>	H. Arbman B. Stjernqvist
<b>Grave type</b>	Gallery grave
<b>MNI</b>	15
<b>No. Adults</b>	13
<b>No. Juveniles</b>	2
<b>No. Males</b>	6
<b>No. Females</b>	3
<b><sup>14</sup>C analysis</b>	Yes
<b><sup>13</sup>C ‰(mean)</b>	-20.42±0.49 (n=5)
<b><sup>15</sup>N ‰(mean)</b>	9.31±0.8 (n=5)
<b>Trauma</b>	10
<b>Cribra orbitalia</b>	5
<b>Enamel hypoplasia</b>	7
<b>Dental caries</b>	9
<b>Schmorl's nodes</b>	7
<b>OA</b>	4
<b>Periostitis</b>	3
<b>Pathology other</b>	OD in one hip (sin) and one knee; IVD in 1 cervical and 5 lumbar vertebrae; Bowing in 1 femur (dxt).

ID	18/37
<b>Region</b>	Scania
<b>Parish</b>	Vellinge
<b>Site name</b>	Kyhlbjersbacken
<b>Raä no.</b>	Vellinge 5:1
<b>Inventory no.</b>	LUHM 27499/ SHM 20598
<b>Year of excavation</b>	1934-1935
<b>Excavator/s</b>	F. Hansen
<b>Grave type</b>	Flat burial
<b>MNI</b>	9/2
<b>No. Adults</b>	4/1
<b>No. Juveniles</b>	5/1
<b>No. Males</b>	1
<b>No. Females</b>	2
<b><sup>14</sup>C analysis</b>	Yes
<b><sup>13</sup>C‰ (mean)</b>	-20.28±0.35(n=4)
<b><sup>15</sup>N‰(mean)</b>	10.88±0.53 (n=4)
<b>Trauma</b>	3
<b>Cribra orbitalia</b>	7 (4)
<b>Enamel hypoplasia</b>	4
<b>Dental caries</b>	3
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	3
<b>Pathology other</b>	Parietal thinning in one individual

**Comment:** () indicates number of individuals.

<b>ID</b>	19
<b>Region</b>	Scania
<b>Parish</b>	Skepparslöv
<b>Site name</b>	Öllsjö 7
<b>Raä no.</b>	Skepparslöv 81:1
<b>Inventory no.</b>	LUHM 28775
<b>Year of excavation</b>	1943
<b>Excavator/s</b>	S. Hommerberg
<b>Grave type</b>	Gallery grave (re-built passage grave)
<b>MNI</b>	8
<b>No. Adults</b>	6
<b>No. Juveniles</b>	2
<b>No. Males</b>	4
<b>No. Females</b>	2
<b><sup>14</sup>C analysis</b>	Yes
<b><sup>13</sup>C‰(mean)</b>	-20.53±0.37 (n=8)
<b><sup>15</sup>N‰(mean)</b>	9.02±0.59 (n=8)
<b>Trauma</b>	2
<b>Cribra orbitalia</b>	
<b>Enamel hypoplasia</b>	
<b>Dental caries</b>	3
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	1
<b>Pathology other</b>	

ID	20
Region	Scania
Parish	Kiaby
Site name	Kiaby 80:1
Raä no.	Kiaby 31:1
Inventory no.	LUHM 28916
Year of excavation	1949
Excavator/s	A. Bagge?
Grave type	Flat burial
MNI	4
No. Adults	3
No. Juveniles	1
No. Males	2
No. Females	1
<sup>14</sup> C analysis	(In Bergerbrant et al. 2017)
<sup>13</sup> C‰	
<sup>15</sup> N‰	
Trauma	
Cribra orbitalia	2 (1)
Enamel hypoplasia	
Dental caries	1
Schmorl's nodes	
OA	
Periostitis	1
Pathology other	Individual III: Bowed femur (sin).

Comment: () indicates number of individuals.

<b>ID</b>	21
<b>Region</b>	Scania
<b>Parish</b>	Västra Virestad
<b>Site name</b>	Västra Virestad 19
<b>Raä no.</b>	Västra Virestad 19
<b>Inventory no.</b>	LUHM 18577
<b>Year of excavation</b>	1911
<b>Excavator/-s</b>	O. Rydbäck
<b>Grave type</b>	Flat burial
<b>MNI</b>	6
<b>No. Adults</b>	4
<b>No. Juveniles</b>	2
<b>No. Males</b>	1
<b>No. Females</b>	2
<b><sup>14</sup>C analysis</b>	(In Bergerbrant et al. 2017)
<b><sup>13</sup>C‰</b>	
<b><sup>15</sup>N‰</b>	
<b>Trauma</b>	1
<b>Cribra orbitalia</b>	4
<b>Enamel hypoplasia</b>	3 (1)
<b>Dental caries</b>	2
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	

**Comment:** Corpus fracture on axis resulting in ankylosis of second and third cervical vertebrae and osteophytes of third-fourth cervical vertebrae and pitting of atlas. () indicates number of individuals.

<b>ID</b>	22
<b>Region</b>	Scania
<b>Parish</b>	Bollerup
<b>Site name</b>	Bollerups gård
<b>Raä no.</b>	Bollerup 4:1
<b>Inventory no.</b>	LUHM 28204
<b>Year of excavation</b>	1935
<b>Excavator/-s</b>	F. Hansen
<b>Grave type</b>	Flat burial
<b>MNI</b>	1
<b>No. Adults</b>	0
<b>No. Juveniles</b>	1
<b>No. Males</b>	
<b>No. Females</b>	
<b><sup>14</sup>C analysis</b>	Yes
<b><sup>13</sup>C‰</b>	-19.9
<b><sup>15</sup>N‰</b>	10.5
<b>Trauma</b>	
<b>Cribra orbitalia</b>	
<b>Enamel hypoplasia</b>	
<b>Dental caries</b>	
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	

<b>ID</b>	23
<b>Region</b>	Scania
<b>Parish</b>	Österslöv
<b>Site name</b>	Österslöv 57:1
<b>Raä no.</b>	Österslöv 57:1
<b>Inventory no.</b>	LUHM 26810
<b>Year of excavation</b>	1932
<b>Excavator/s</b>	F. Hansen
<b>Grave type</b>	Gallery grave
<b>MNI</b>	2
<b>No. Adults</b>	2
<b>No. Juveniles</b>	0
<b>No. Males</b>	
<b>No. Females</b>	1
<b><sup>14</sup>C analysis</b>	No
<b><sup>13</sup>C‰</b>	
<b><sup>15</sup>N‰</b>	
<b>Trauma</b>	
<b>Cribra orbitalia</b>	
<b>Enamel hypoplasia</b>	
<b>Dental caries</b>	2
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	

<b>ID</b>	24
<b>Region</b>	Scania
<b>Parish</b>	Hyllie
<b>Site name</b>	Järavallen
<b>Raä no.</b>	n.a.
<b>Inventory no.</b>	LUHM 17024
<b>Year of excavation</b>	1895
<b>Excavator/-s</b>	n.a.
<b>Grave type</b>	Flat burial
<b>MNI</b>	1
<b>No. Adults</b>	1
<b>No. Juveniles</b>	0
<b>No. Males</b>	
<b>No. Females</b>	
<b><sup>14</sup>C analysis</b>	No
<b><sup>13</sup>C‰</b>	
<b><sup>15</sup>N‰</b>	
<b>Trauma</b>	
<b>Cribra orbitalia</b>	
<b>Enamel hypoplasia</b>	
<b>Dental caries</b>	
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	

<b>ID</b>	27
<b>Region</b>	Scania
<b>Parish</b>	Gustav Adolf
<b>Site name</b>	Riksvägen
<b>Raä no.</b>	n.a.
<b>Inventory no.</b>	SHM 22059
<b>Year of excavation</b>	n.a.
<b>Excavator/-s</b>	n.a.
<b>Grave type</b>	Barrow
<b>MNI</b>	3
<b>No. Adults</b>	1
<b>No. Juveniles</b>	2
<b>No. Males</b>	1
<b>No. Females</b>	
<b><sup>14</sup>C analysis</b>	No
<b><sup>13</sup>C‰</b>	
<b><sup>15</sup>N‰</b>	
<b>Trauma</b>	1
<b>Cribra orbitalia</b>	
<b>Enamel hypoplasia</b>	1
<b>Dental caries</b>	
<b>Schmorl's nodes</b>	1
<b>OA</b>	
<b>Periostitis</b>	2
<b>Pathology other</b>	

<b>ID</b>	28
<b>Region</b>	Scania
<b>Parish</b>	Håslöv
<b>Site name</b>	Håslöv 5
<b>Raä no.</b>	n.a.
<b>Inventory no.</b>	SHM 22250
<b>Year of excavation</b>	F. Hansen
<b>Excavator/-s</b>	1937
<b>Grave type</b>	Gallery grave
<b>MNI</b>	12
<b>No. Adults</b>	11
<b>No. Juveniles</b>	1
<b>No. Males</b>	1
<b>No. Females</b>	
<b><sup>14</sup>C analysis</b>	Yes
<b><sup>13</sup>C‰</b>	
<b><sup>15</sup>N‰</b>	
<b>Trauma</b>	
<b>Cribra orbitalia</b>	
<b>Enamel hypoplasia</b>	3
<b>Dental caries</b>	
<b>Schmorl's nodes</b>	1
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	DJD talus (sin+dxt)

<b>ID</b>	29
<b>Region</b>	Scania
<b>Parish</b>	Stora Köpinge
<b>Site name</b>	Hemmanet no. 15
<b>Raä no.</b>	n.a.
<b>Inventory no.</b>	SHM 5654
<b>Year of excavation</b>	1876?
<b>Excavator/s</b>	A. Kurck
<b>Grave type</b>	Barrow
<b>MNI</b>	7
<b>No. Adults</b>	6
<b>No. Juveniles</b>	1
<b>No. Males</b>	4
<b>No. Females</b>	2
<b><sup>14</sup>C analysis</b>	No
<b><sup>13</sup>C‰</b>	
<b><sup>15</sup>N‰</b>	
<b>Trauma</b>	2
<b>Cribra orbitalia</b>	2
<b>Enamel hypoplasia</b>	
<b>Dental caries</b>	2
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	

<b>ID</b>	30
<b>Region</b>	Scania
<b>Parish</b>	Kiaby
<b>Site name</b>	Bäckaskogs kungsgård
<b>Raä no.</b>	Kiaby 37:1
<b>Inventory no.</b>	SHM 21544
<b>Year of excavation</b>	1936
<b>Excavator/s</b>	F: Hansen
<b>Grave type</b>	Cairn
<b>MNI</b>	2
<b>No. Adults</b>	2
<b>No. Juveniles</b>	0
<b>No. Males</b>	1
<b>No. Females</b>	1
<b><sup>14</sup>C analysis</b>	No
<b><sup>13</sup>C‰</b>	
<b><sup>15</sup>N‰</b>	
<b>Trauma</b>	2
<b>Cribra orbitalia</b>	4 (2)
<b>Enamel hypoplasia</b>	
<b>Dental caries</b>	
<b>Schmorl's nodes</b>	
<b>OA</b>	8
<b>Periostitis</b>	
<b>Pathology other</b>	DJD in several joints; probable osteoporosis

**Comment:** () indicates number of individuals.

<b>ID</b>	31
<b>Region</b>	Scania
<b>Parish</b>	Håslöv
<b>Site name</b>	Åkes hög
<b>Raä no.</b>	Håslöv 1:1
<b>Inventory no.</b>	SHM 10288
<b>Year of excavation</b>	n.a.
<b>Excavator/s</b>	O. Montelius
<b>Grave type</b>	Barrow
<b>MNI</b>	4
<b>No. Adults</b>	2
<b>No. Juveniles</b>	2
<b>No. Males</b>	1
<b>No. Females</b>	1
<b><sup>14</sup>C analysis</b>	No
<b><sup>13</sup>C‰</b>	
<b><sup>15</sup>N‰</b>	
<b>Trauma</b>	
<b>Cribra orbitalia</b>	2 (1)
<b>Enamel hypoplasia</b>	1
<b>Dental caries</b>	
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	

**Comment:** ( ) indicates number of individuals.

<b>ID</b>	32
<b>Region</b>	Scania
<b>Parish</b>	Hammarlöv
<b>Site name</b>	Hammarlöv no. 6
<b>Raä no.</b>	n.a.
<b>Inventory no.</b>	SHM 8742
<b>Year of excavation</b>	1890
<b>Excavator/-s</b>	O. Montelius
<b>Grave type</b>	Barrow
<b>MNI</b>	1
<b>No. Adults</b>	1
<b>No. Juveniles</b>	
<b>No. Males</b>	1
<b>No. Females</b>	
<b><sup>14</sup>C analysis</b>	No
<b><sup>13</sup>C‰</b>	
<b><sup>15</sup>N‰</b>	
<b>Trauma</b>	1
<b>Cribra orbitalia</b>	
<b>Enamel hypoplasia</b>	
<b>Dental caries</b>	
<b>Schmorl's nodes</b>	
<b>OA</b>	1
<b>Periostitis</b>	
<b>Pathology other</b>	

**Comment:** Healed fracture of right distal femur with following osteoarthritis.

<b>ID</b>	33
<b>Region</b>	Scania
<b>Parish</b>	Hammarlöv
<b>Site name</b>	Bonhög
<b>Rää no.</b>	Hammarlöv 4:1
<b>Inventory no.</b>	SHM 9169
<b>Year of excavation</b>	1892
<b>Excavator/-s</b>	O. Montelius
<b>Grave type</b>	Gallery grave
<b>MNI</b>	1
<b>No. Adults</b>	1
<b>No. Juveniles</b>	
<b>No. Males</b>	
<b>No. Females</b>	1
<b><sup>14</sup>C analysis</b>	No
<b><sup>13</sup>C‰</b>	
<b><sup>15</sup>N‰</b>	
<b>Trauma</b>	1
<b>Cribra orbitalia</b>	
<b>Enamel hypoplasia</b>	
<b>Dental caries</b>	
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	OD in left acetabulum

<b>ID</b>	34
<b>Region</b>	Scania
<b>Parish</b>	Kiaby
<b>Site name</b>	Kiaby mosse
<b>Raä no.</b>	Kiaby 24:1
<b>Inventory no.</b>	SHM 15779
<b>Year of excavation</b>	1916
<b>Excavator/-s</b>	K. Kjellmark
<b>Grave type</b>	Flat burial
<b>MNI</b>	2
<b>No. Adults</b>	1
<b>No. Juveniles</b>	1
<b>No. Males</b>	1
<b>No. Females</b>	
<b><sup>14</sup>C analysis</b>	No
<b><sup>13</sup>C‰</b>	
<b><sup>15</sup>N‰</b>	
<b>Trauma</b>	
<b>Cribra orbitalia</b>	2 (1)
<b>Enamel hypoplasia</b>	4 (2)
<b>Dental caries</b>	2
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	

**Comment:** () indicates number of individuals.

<b>ID</b>	35
<b>Region</b>	Scania
<b>Parish</b>	Österslöv
<b>Site name</b>	Österslöv 24
<b>Raä no.</b>	Österslöv 137:2
<b>Inventory no.</b>	SHM 4125
<b>Year of excavation</b>	1869
<b>Excavator/-s</b>	H? Hildebrand
<b>Grave type</b>	Barrow
<b>MNI</b>	3
<b>No. Adults</b>	2
<b>No. Juveniles</b>	1
<b>No. Males</b>	1
<b>No. Females</b>	1
<b><sup>14</sup>C analysis</b>	Yes
<b><sup>13</sup>C‰ (mean)</b>	-21.05±0.64 (n=2)
<b><sup>15</sup>N‰ (mean)</b>	9.75±0.92 (n=2)
<b>Trauma</b>	
<b>Cribra orbitalia</b>	
<b>Enamel hypoplasia</b>	
<b>Dental caries</b>	
<b>Schmorl's nodes</b>	3
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	

<b>ID</b>	36
<b>Region</b>	Scania
<b>Parish</b>	Vellinge
<b>Site name</b>	Vellinge 27
<b>Raä no.</b>	Vellinge 11:1
<b>Inventory no.</b>	SHM 13937
<b>Year of excavation</b>	1909
<b>Excavator/s</b>	O. Rydbeck
<b>Grave type</b>	Flat burial
<b>MNI</b>	4
<b>No. Adults</b>	2
<b>No. Juveniles</b>	2
<b>No. Males</b>	1
<b>No. Females</b>	1
<b><sup>14</sup>C analysis</b>	Yes
<b><sup>13</sup>C‰ (mean)</b>	-20.7±0.42 (n=2)
<b><sup>15</sup>N‰ (mean)</b>	9.85±1.34 (n=2)
<b>Trauma</b>	1
<b>Cribra orbitalia</b>	2 (1)
<b>Enamel hypoplasia</b>	
<b>Dental caries</b>	4
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	IVD: 4 thoracic vertebrae

**Comment:** () indicates number of individuals.

<b>ID</b>	38
<b>Region</b>	Scania
<b>Parish</b>	Simris
<b>Site name</b>	Viarp
<b>Raä no.</b>	Simris 2:1
<b>Inventory no.</b>	SHM 7731
<b>Year of excavation</b>	1885
<b>Excavator/-s</b>	O. Montelius
<b>Grave type</b>	Barrow
<b>MNI</b>	1
<b>No. Adults</b>	0
<b>No. Juveniles</b>	1
<b>No. Males</b>	
<b>No. Females</b>	
<b><sup>14</sup>C analysis</b>	No
<b><sup>13</sup>C‰</b>	
<b><sup>15</sup>N‰</b>	
<b>Trauma</b>	
<b>Cribra orbitalia</b>	
<b>Enamel hypoplasia</b>	
<b>Dental caries</b>	
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	

ID	39
Region	Scania
Parish	Nosaby
Site name	Möllebacken
Raä no.	Nosaby 18:1
Inventory no.	SHM 6906
Year of excavation	1882
Excavator/s	A. Ahlén
Grave type	Gallery grave
MNI	21
No. Adults	16
No. Juveniles	5
No. Males	6
No. Females	5
<sup>14</sup> C analysis	Yes
<sup>13</sup> C‰ (mean)	-19.8±0 (n=2)
<sup>15</sup> N‰ (mean)	10.4±0.42 (n=2)
Trauma	10
Cribra orbitalia	
Enamel hypoplasia	
Dental caries	7
Schmorl's nodes	7
OA	1
Periostitis	1
Pathology other	

**Comment:** Traumas correspond to compression fractures on 7 lower thoracal and upper lumbar vertebrae. One healed radius fracture, one tibia fracture and one peri-mortem frontal trauma.

<b>ID</b>	41
<b>Region</b>	Scania
<b>Parish</b>	Västra Klagstorp
<b>Site name</b>	Solnäs 19
<b>Raä no.</b>	n.a.
<b>Inventory no.</b>	LUHM 25568
<b>Year of excavation</b>	1929
<b>Excavator/s</b>	F. Hansen
<b>Grave type</b>	Barrow
<b>MNI</b>	3
<b>No. Adults</b>	2
<b>No. Juveniles</b>	1
<b>No. Males</b>	0
<b>No. Females</b>	2
<b><sup>14</sup>C analysis</b>	No
<b><sup>13</sup>C‰</b>	
<b><sup>15</sup>N‰</b>	
<b>Trauma</b>	1
<b>Cribra orbitalia</b>	
<b>Enamel hypoplasia</b>	
<b>Dental caries</b>	
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	Ankylosis in three thoracal vertebrae; malformed juvenile femur

<b>ID</b>	42
<b>Region</b>	Scania
<b>Parish</b>	Skepparslöv
<b>Site name</b>	Skepparslöv
<b>Raä no.</b>	n.a.
<b>Inventory no.</b>	LUHM 20804
<b>Year of excavation</b>	1922-1923
<b>Excavator/-s</b>	The teacher Rydholm
<b>Grave type</b>	Flat burial
<b>MNI</b>	1
<b>No. Adults</b>	0
<b>No. Juveniles</b>	1
<b>No. Males</b>	
<b>No. Females</b>	
<b><sup>14</sup>C analysis</b>	No
<b><sup>13</sup>C‰</b>	
<b><sup>15</sup>N‰</b>	
<b>Trauma</b>	
<b>Cribra orbitalia</b>	2 (1)
<b>Enamel hypoplasia</b>	
<b>Dental caries</b>	
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	

**Comment:** () indicates number of individuals.

<b>ID</b>	44
<b>Region</b>	Scania
<b>Parish</b>	Hyllie
<b>Site name</b>	Knuts backe
<b>Raä no.</b>	n.a.
<b>Inventory no.</b>	LUHM 17042
<b>Year of excavation</b>	1944
<b>Excavator/-s</b>	F. Hansen
<b>Grave type</b>	
<b>MNI</b>	1
<b>No. Adults</b>	1
<b>No. Juveniles</b>	0
<b>No. Males</b>	
<b>No. Females</b>	
<b><sup>14</sup>C analysis</b>	No
<b><sup>13</sup>C‰</b>	
<b><sup>15</sup>N‰</b>	
<b>Trauma</b>	
<b>Cribra orbitalia</b>	
<b>Enamel hypoplasia</b>	
<b>Dental caries</b>	
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	

<b>ID</b>	45
<b>Region</b>	Scania
<b>Parish</b>	Skepparslöv
<b>Site name</b>	Skepparslöv 20
<b>Raä no.</b>	Skepparslöv 18:1
<b>Inventory no.</b>	LUHM 28784
<b>Year of excavation</b>	1948
<b>Excavator/-s</b>	B. Stjernqvist
<b>Grave type</b>	Barrow
<b>MNI</b>	1
<b>No. Adults</b>	0
<b>No. Juveniles</b>	1
<b>No. Males</b>	
<b>No. Females</b>	
<b><sup>14</sup>C analysis</b>	No
<b><sup>13</sup>C‰</b>	
<b><sup>15</sup>N‰</b>	
<b>Trauma</b>	
<b>Cribra orbitalia</b>	
<b>Enamel hypoplasia</b>	
<b>Dental caries</b>	
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	

ID	46
Region	Scania
Parish	Hammenhög
Site name	Hammenhög 26
Raä no.	n.a.
Inventory no.	LUHM
Year of excavation	1927
Excavator/s	F. Hansen
Grave type	Flat burial
MNI	3
No. Adults	2
No. Juveniles	1
No. Males	1
No. Females	1
<sup>14</sup> C analysis	No
<sup>13</sup> C‰	
<sup>15</sup> N‰	
Trauma	
Cribra orbitalia	
Enamel hypoplasia	
Dental caries	
Schmorl's nodes	
OA	
Periostitis	
Pathology other	

<b>ID</b>	47
<b>Region</b>	Scania
<b>Parish</b>	Hammenhög
<b>Site name</b>	Hammenhög 35
<b>Raä no.</b>	n.a.
<b>Inventory no.</b>	LUHM 32824
<b>Year of excavation</b>	1927
<b>Excavator/s</b>	F. Hansen
<b>Grave type</b>	Flat burial
<b>MNI</b>	7
<b>No. Adults</b>	6
<b>No. Juveniles</b>	1
<b>No. Males</b>	3
<b>No. Females</b>	
<b><sup>14</sup>C analysis</b>	No
<b><sup>13</sup>C‰</b>	
<b><sup>15</sup>N‰</b>	
<b>Trauma</b>	
<b>Cribra orbitalia</b>	
<b>Enamel hypoplasia</b>	
<b>Dental caries</b>	2
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	

<b>ID</b>	48
<b>Region</b>	Scania
<b>Parish</b>	Maglarp
<b>Site name</b>	Ahlbäcksbacken
<b>Raä no.</b>	Maglarp 23:1
<b>Inventory no.</b>	LUHM, no number
<b>Year of excavation</b>	1977
<b>Excavator/s</b>	B. Jacobsson
<b>Grave type</b>	Flat burial
<b>MNI</b>	2
<b>No. Adults</b>	2
<b>No. Juveniles</b>	0
<b>No. Males</b>	0
<b>No. Females</b>	2
<b><sup>14</sup>C analysis</b>	Yes
<b><sup>13</sup>C‰ (mean)</b>	-20.8±0.28 (n=2)
<b><sup>15</sup>N‰ (mean)</b>	9.95±0.07 (n=2)
<b>Trauma</b>	
<b>Cribra orbitalia</b>	
<b>Enamel hypoplasia</b>	1
<b>Dental caries</b>	
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	

ID	51
Region	Scania
Parish	Lilla Isie
Site name	Snorthög
Raä no.	Lilla Isie 23:1
Inventory no.	LUHM 28424
Year of excavation	1938
Excavator/-s	B-M. Vifot
Grave type	Flat burial
MNI	11
No. Adults	10
No. Juveniles	1
No. Males	6
No. Females	2
<sup>14</sup> C analysis	Yes
<sup>13</sup> C‰ (mean)	-20.2±0.43 (n=5)
<sup>15</sup> N‰ (mean)	10.33± 0.87 (n=5)
Trauma	1
Cribra orbitalia	
Enamel hypoplasia	
Dental caries	
Schmorl's nodes	5
OA	1
Periostitis	1
Pathology other	

<b>ID</b>	43
<b>Region</b>	Scania
<b>Parish</b>	Östra Torp
<b>Site name</b>	Östra Torp 4
<b>Råä no.</b>	Östra Torp 25:1
<b>Inventory no.</b>	LUHM 28423
<b>Year of excavation</b>	1938
<b>Excavator/-s</b>	B-M. Vifot
<b>Grave type</b>	Flat burial
<b>MNI</b>	1
<b>No. Adults</b>	1
<b>No. Juveniles</b>	0
<b>No. Males</b>	1
<b>No. Females</b>	0
<b><sup>14</sup>C analysis</b>	Yes
<b><sup>13</sup>C‰</b>	-19.8
<b><sup>15</sup>N‰</b>	10.6
<b>Typological dating</b>	MNB/BAC
<b>Trauma</b>	3
<b>Cribra orbitalia</b>	
<b>Enamel hypoplasia</b>	
<b>Dental caries</b>	
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	

<b>ID</b>	15
<b>Region</b>	Västergötland
<b>Parish</b>	Torbjörntorp
<b>Site name</b>	Berga kalkbrott
<b>Raä no.</b>	Torbjörntorp 31
<b>Inventory no.</b>	SHM 18522
<b>Year of excavation</b>	1927
<b>Excavator/-s</b>	K. E. Sahlström
<b>Grave type</b>	Gallery grave
<b>MNI</b>	20
<b>No. Adults</b>	11
<b>No. Juveniles</b>	9
<b>No. Males</b>	6
<b>No. Females</b>	4
<b><sup>14</sup>C analysis</b>	In Blank (manuscript)
<b><sup>13</sup>C‰</b>	
<b><sup>15</sup>N‰</b>	
<b>Typological dating</b>	LN-EBA
<b>Trauma</b>	18
<b>Cribra orbitalia</b>	5
<b>Enamel hypoplasia</b>	26
<b>Dental caries</b>	17
<b>Schmorl's nodes</b>	4
<b>OA</b>	2
<b>Periostitis</b>	1
<b>Pathology other</b>	DJD in several vertebrae

<b>ID</b>	16
<b>Region</b>	Västergötland
<b>Parish</b>	Medelplana
<b>Site name</b>	Hellekis
<b>Raä no.</b>	Medelplana 54:1
<b>Inventory no.</b>	SHM 15660
<b>Year of excavation</b>	1916
<b>Excavator/s</b>	B. Schnittger
<b>Grave type</b>	Gallery grave
<b>MNI</b>	20
<b>No. Adults</b>	17
<b>No. Juveniles</b>	3
<b>No. Males</b>	6
<b>No. Females</b>	8
<b><sup>14</sup>C analysis</b>	In Blank (manuscript)
<b><sup>13</sup>C‰</b>	
<b><sup>15</sup>N‰</b>	
<b>Typological dating</b>	LN-EBA
<b>Trauma</b>	13
<b>Cribra orbitalia</b>	7
<b>Enamel hypoplasia</b>	24
<b>Dental caries</b>	11
<b>Schmorl's nodes</b>	2
<b>OA</b>	1
<b>Periostitis</b>	
<b>Pathology other</b>	One individual with button osteoma. One juvenile with erosive pathology on internal occipital.

<b>ID</b>	25
<b>Region</b>	Västergötland
<b>Parish</b>	Medelplana
<b>Site name</b>	Medelplana 27
<b>Raä no.</b>	Medelplana 27:1
<b>Inventory no.</b>	SHM 7881
<b>Year of excavation</b>	1922
<b>Excavator/-s</b>	n.a.
<b>Grave type</b>	Gallery grave
<b>MNI</b>	7
<b>No. Adults</b>	6
<b>No. Juveniles</b>	1
<b>No. Males</b>	3
<b>No. Females</b>	3
<b><sup>14</sup>C analysis</b>	No
<b><sup>13</sup>C ‰</b>	
<b><sup>15</sup>N ‰</b>	
<b>Typological dating</b>	LN-EBA
<b>Trauma</b>	1
<b>Cribra orbitalia</b>	1
<b>Enamel hypoplasia</b>	
<b>Dental caries</b>	
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	

<b>ID</b>	17
<b>Region</b>	Västergötland
<b>Parish</b>	Falköping
<b>Site name</b>	Fredriksberg
<b>Raä no.</b>	Falköping stad 5
<b>Inventory no.</b>	SHM 32384
<b>Year of excavation</b>	1974
<b>Excavator/-s</b>	E. Weiler
<b>Grave type</b>	Gallery grave
<b>MNI</b>	28
<b>No. Adults</b>	19
<b>No. Juveniles</b>	9
<b>No. Males</b>	8
<b>No. Females</b>	6
<b><sup>14</sup>C analysis</b>	Yes
<b><sup>13</sup>C (mean)‰</b>	-20.9±0.3 (n=17)
<b><sup>15</sup>N (mean)‰</b>	9.3±0.8 (n=17)
<b>Typological dating</b>	LN-EBA
<b>Trauma</b>	3
<b>Cribra orbitalia</b>	0
<b>Enamel hypoplasia</b>	11
<b>Dental caries</b>	16
<b>Schmorl's nodes</b>	0
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	Ankylosis in cuneiforme laterale-cuneiforme intermedium dxt; cuboid-mt4t; vertebra cervicalis 2-3.

<b>ID</b>	26
<b>Region</b>	Västergötland
<b>Parish</b>	Timmersdala
<b>Site name</b>	Skolhuset
<b>Raä no.</b>	Timmersdala 5:1
<b>Inventory no.</b>	SHM 5974
<b>Year of excavation</b>	1877
<b>Excavator/-s</b>	K. Torin
<b>Grave type</b>	Gallery grave
<b>MNI</b>	16
<b>No. Adults</b>	13
<b>No. Juveniles</b>	3
<b>No. Males</b>	5
<b>No. Females</b>	8
<b><sup>14</sup>C analysis</b>	No
<b><sup>13</sup>C (mean)‰</b>	
<b><sup>15</sup>N (mean)‰</b>	
<b>Typological dating</b>	LN-EBA
<b>Trauma</b>	4
<b>Cribra orbitalia</b>	4
<b>Enamel hypoplasia</b>	7
<b>Dental caries</b>	13
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	One individual with bilateral parietal thinning, probably due to old age.

<b>ID</b>	49
<b>Region</b>	Östergötland
<b>Parish</b>	Roglösa
<b>Site name</b>	Bårstad
<b>Raä no.</b>	Roglösa 37:1
<b>Inventory no.</b>	SHM 18577
<b>Year of excavation</b>	1928
<b>Excavator/-s</b>	B. Cnattingius
<b>Grave type</b>	n.a.
<b>MNI</b>	16
<b>No. Adults</b>	6
<b>No. Juveniles</b>	10
<b>No. Males</b>	1
<b>No. Females</b>	3
<b><sup>14</sup>C analysis</b>	Yes
<b><sup>13</sup>C (mean)‰</b>	
<b><sup>15</sup>N (mean)‰</b>	
<b>Typological dating</b>	LN-EBA
<b>Trauma</b>	
<b>Cribra orbitalia</b>	
<b>Enamel hypoplasia</b>	
<b>Dental caries</b>	6
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	

<b>ID</b>	50
<b>Region</b>	Östergötland
<b>Parish</b>	Rapestad
<b>Site name</b>	Rapestad 1:1
<b>Raä no.</b>	Rapestad 22:1
<b>Inventory no.</b>	SHM 30398
<b>Year of excavation</b>	1974
<b>Excavator/-s</b>	n.a.
<b>Grave type</b>	Gallery grave
<b>MNI</b>	3
<b>No. Adults</b>	1
<b>No. Juveniles</b>	2
<b>No. Males</b>	1
<b>No. Females</b>	0
<b><sup>14</sup>C analysis</b>	No
<b><sup>13</sup>C (mean)‰</b>	
<b><sup>15</sup>N (mean)‰</b>	
<b>Typological dating</b>	LN-EBA
<b>Trauma</b>	2
<b>Cribra orbitalia</b>	
<b>Enamel hypoplasia</b>	4
<b>Dental caries</b>	2
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	

<b>ID</b>	40
<b>Region</b>	Närke
<b>Parish</b>	Hidinge
<b>Site name</b>	Lanna, Västergård
<b>Raä no.</b>	Hidinge 3:1
<b>Inventory no.</b>	SHM 18641
<b>Year of excavation</b>	1914
<b>Excavator/-s</b>	B. Schnittger H. Hedberg
<b>Grave type</b>	Gallery grave
<b>MNI</b>	5
<b>No. Adults</b>	4
<b>No. Juveniles</b>	1
<b>No. Males</b>	1
<b>No. Females</b>	3
<b><sup>14</sup>C analysis</b>	Yes
<b><sup>13</sup>C (mean)</b>	-20.88 ±0.13( n=5)
<b><sup>15</sup>N (mean)</b>	10.2 ±0.6 (n=5)
<b>Typological dating</b>	LN-EBA
<b>Trauma</b>	
<b>Cribra orbitalia</b>	
<b>Enamel hypoplasia</b>	0
<b>Dental caries</b>	3
<b>Schmorl's nodes</b>	
<b>OA</b>	
<b>Periostitis</b>	
<b>Pathology other</b>	

ID	12
<b>Region</b>	Uppland
<b>Parish</b>	Skuttunge
<b>Site name</b>	Dragby
<b>Raä no.</b>	Bälinge 86:3
<b>Inventory no.</b>	n.a.
<b>Year of excavation</b>	1960
<b>Excavator/-s</b>	M. Stenberger
<b>Grave type</b>	Gallery grave
<b>MNI</b>	30
<b>No. Adults</b>	26
<b>No. Juveniles</b>	4
<b>No. Males</b>	7
<b>No. Females</b>	4
<b><sup>14</sup>C analysis</b>	(In Roumelis, 2004)
<b><sup>13</sup>C</b>	(In Roumelis, 2004)
<b><sup>15</sup>N</b>	(In Roumelis, 2004)
<b>Typological dating</b>	LN-EBA
<b>Trauma</b>	4
<b>Cribra orbitalia</b>	9
<b>Enamel hypoplasia</b>	13
<b>Dental caries</b>	26
<b>Schmorl's nodes</b>	0
<b>OA</b>	1
<b>Periostitis</b>	1
<b>Pathology other</b>	



# Appendix 2: Radiocarbon dates and Stable Isotopes

Radiocarbon dates and stable isotope results from analyses conducted within this thesis project; both human and animal skeletal remains.

## Human sample

Locality	Individual	Material	Date BP	+/-	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	C:N ratio	LabNo
Abbekås 1	5:1	Mand.	3453	35	-20.0	10.14	3.24	UBA-22837
Abbekås 1	5:2	Mand.	3387	38	-20.0	9.44	3.21	UBA-22840
Abbekås 1	15	Mand.	3111	35	-20.0	10.15	3.31	UBA-22838
Abbekås 1	14	Mand.	3144	49	-19.9	10.38	3.24	UBA-22835
Abbekås 1	11	Mand.	3197	21	-20.9	9.28	3.25	UBA-22836
Abbekås 1	6	Mand.	2645	34	-20.0	8.96	3.16	UBA-22839
Abbekås 1	7	Mand.	3131	33	-20.4	9.28	3.43	UBA-22841
Abbekås 1	1	Hum.	3700	50			n.a.	LuS 10618
Abbekås 1	5:1	Hum.	3600	50			n.a.	LuS 10619
Abbekås 1	5:2	Hum.	3585	50			n.a.	LuS 10620
Abbekås 2	7	Hum.	3410	30	-19.3	10.5	3.16	UBA-23992
Ahlbäcksbacken	1	Mand.	3588	30	-21	9.9	3.29	UBA-24004
Ahlbäcksbacken	2	Mand.	3604	30	-20.6	10	3.23	UBA-24005
Bollerup	1	tooth	3496	32	-19.9	10.5	3.19	UBA-27863
Bårstad	a	PM2-	3295	45			n.a.	LuS 11855

Locality	Individual	Material	Date BP	+/-	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	C:N ratio	LabNo
<b>Bårstad</b>	b	PM2-	3520	45			n.a.	LuS 11856
<b>Falköping stad 5</b>	F83III:1	M2-	3420	33	-20.9	10.6	3.18	UBA-30770
<b>Falköping stad 5</b>	F139II:2	M2-	3598	31	-21.1	9.1	3.18	UBA-30764
<b>Falköping stad 5</b>	F90	dpm2-	3500	31	-20	10.8	3.24	UBA-30758
<b>Falköping stad 5</b>	F115VII:2	M2-	3654	34	-20.6	8.9	3.16	UBA-30763
<b>Falköping stad 5</b>	F132VI:3	M2-	3639	35	-20.7	8.9	3.22	UBA-30737
<b>Falköping stad 5</b>	F117	M2-	3679	32	-20.5	9.1	3.16	UBA-30766
<b>Falköping stad 5</b>	F108IV:3	M2-	3562	49	-21	10.7	3.15	UBA-30767
<b>Falköping stad 5</b>	F98	dpm2-	3640	33	-20.8	9.9	3.22	UBA-30774
<b>Falköping stad 5</b>	F147VI:4	M2-	3624	31	-20.6	8.4	3.21	UBA-30745
<b>Falköping stad 5</b>	F123	M2-	3491	33	-21.1	8.5	3.15	UBA-30768
<b>Falköping stad 5</b>	F122	M2-	3602	33	-20.8	8.3	3.17	UBA-30765
<b>Falköping stad 5</b>	F119	dpm2-	3638	35	-20.4	10.4	3.21	UBA-30771
<b>Falköping stad 5</b>	F121	M2-	3595	33	-20.8	9.3	3.17	UBA-30749
<b>Falköping stad 5</b>	F134	M1-	3631	42	-20.4	9.3	3.23	UBA-30735
<b>Falköping stad 5</b>	F69	M2-	3642	32	-20.5	9.1	3.18	UBA-30742
<b>Falköping stad 5</b>	F124	M2-	3600	33	-21.4	9.9	3.21	UBA-30775
<b>Falköping stad 5</b>	F118	M1-	3560	33	-21	8.6	3.15	UBA-30769
<b>Falköping stad 5</b>	F88	dpm2-	3609	41	-21.4	10.5	3.22	UBA-30753
<b>Falköping stad 5</b>	F129V2:2	M1-	3697	37	-21.1	9.5	3.20	UBA-30762
<b>Falköping stad 5</b>	F128	M3-	3680	33	-21.6	9.9	3.19	UBA-30773
<b>Falköping stad 5</b>	F120+132	M1-	3706	36	-20.5	10.8	3.21	UBA-30772
<b>Håslöv 5</b>	A	PM1-	3060	40			n.a.	LuS 11854
<b>Kjyhbjersbacken</b>	1	C-	3675	40			n.a.	LuS 11853
<b>Kyhbjersbacken</b>	6	Mand.	3697	28	-20.4	10.7	3.23	UBA-24000

Locality	Individual	Material	Date BP	+/-	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	C:N ratio	LabNo
Kyhlbjersbacken	12	Mand.	3073	28	-19.9	11.3	3.17	UBA-24001
Kyhlbjersbacken	9	Mand.	3805	53	-20.1	11.3	3.17	UBA-24002
Kyhlbjersbacken	15	Mand.	3537	28	-20.7	10.2	3.21	UBA-24003
Kyhlbjersbacken	a	C-	3675	40			n.a.	LuS 11853
Kyhlbjersbacken	6	Mand.	3715	50			n.a.	LuS 10621
Kyhlbjersbacken	8	Hum.	3675	50			n.a.	LuS 10622
Lanna Västergård	1	PM1+	3442	35	-21.0	10.4	3.17	UBA-30402
Lanna Västergård	2	Mand.	3327	36	-20.7	9.6	3.23	UBA-30403
Lanna Västergård	3	Mand.	3405	51	-21.0	10.4	3.19	UBA-30404
Lanna Västergård	4	Fem.	3509	48	-20.8	9.6	3.23	UBA-30405
Lanna Västergård	5	Mand.	3417	35	-20.9	11	3.21	UBA-30406
Nosaby	c	C-	3381	42	-19.8	10.1	3.17	UBA-30559
Nosaby	f	PM2-	3491	35	-19.8	10.7	3.17	UBA-30560
Nosaby 18	a	C-	3435	40			n.a.	LuS 11849
Nosaby 18	b	PM2-	3580	45			n.a.	LuS 11850
Nosaby 18	d	PM2-	3435	40			n.a.	LuS 11851
Nosaby 18	e	PM2-	3510	40			n.a.	LuS 11852
Rörbäck 10	2	Mand.	3180	45			n.a.	LuS 10623
Rörbäck 10	3	Mand.	3045	45			n.a.	LuS 10624
Snorthög 2	2	Mand.	3616	41	-20.7	10.6	3.34	UBA-22850
Snorthög 4	4	Mand.	3608	32	-19.9	11.3	3.30	UBA-22849
Snorthög 5	5	Mand.	3726	35	-19.7	10.4	3.18	UBA-22851
Snorthög 8	8	Mand.	3694	32	-20.6	10.5	3.27	UBA-22852
Snorthög 9	9	Hum.	3571	32	-19.9	8.9	3.27	UBA-22853
Vellinge 27	Hu7	Max.	3101	46	-20.4	10.8	3.45	UBA-30558

Locality	Individual	Material	Date BP	+/-	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	C:N ratio	LabNo
Vellinge 27	Hu8	PM2-	3748	58	-21.0	8.9	3.21	UBA-30561
Ängamöllan	A	Mand.	3004	40	-20.4	9.5	3.30	UBA-23996
Ängamöllan	B	Mand.	3070	29	-20.1	10.1	3.22	UBA-23997
Ängamöllan	C	Mand.	3105	29	-19.8	9.9	3.22	UBA-23998
Ängamöllan	D	Mand.	3025	34	-20.8	8.9	3.31	UBA-23999
Öllsjö 7	A	Mand.	3308	32	-21.0	8.1	3.47	UBA-22842
Öllsjö 7	B	Mand.	2899	34	-21.0	9.6	3.55	UBA-22843
Öllsjö 7	C	Mand.	3453	32	-20.7	8.8	3.20	UBA-22854
Öllsjö 7	D	Mand.	3512	35	-20.1	9.2	3.22	UBA-22855
Öllsjö 7	G	Mand.	3011	33	-20.4	9.7	3.35	UBA-22857
Öllsjö 7	H	Mand.	3408	34	-20.0	9.4	3.20	UBA-22846
Öllsjö 7	I	Mand.	3130	31	-20.7	8.2	3.33	UBA-22844
Öllsjö 7	J	Mand.	3385	35	-20.5	9.1	3.31	UBA-22845
Österslöv 24	A	tooth	3204	36	-21.5	9.1	3.40	UBA-27865
Österslöv 24	B	tooth	3140	39	-20.6	10.4	3.27	UBA-27864
Östra Torp 4	1	PM	3918	56	-19.8	10.6	3.16	UBA-30562

**Animal sample**

Animal samples from the Scanian site Sandeplan (Raä no. Räng 4:3), Räng parish.

Locality	Individual	Material	Date BP	+/-	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	C:N ratio	LabNo
Sandeplan	Sus 993	Mand.	2863	40	-21.6	8.3	3.17	UBA-30563
Sandeplan	Bos 2053	Mand.	2778	51	-21.2	5.6	3.19	UBA-30564
Sandeplan	Bos 963	Mand.	2802	42	-20.9	5.4	3.2	UBA-30565
Sandeplan	Bos 2078	Mand.	2753	45	-20.8	4.5	3.16	UBA-30566
Sandeplan	O/C 2060	Mand.	2862	41	-20.7	5.8	3.19	UBA-30567
Sandeplan	O/C 1018	Mand.	2834	45	-20.2	6.1	3.19	UBA-30568
Sandeplan	Cervus 164	Scap.	2829	45	-21.6	7.5	3.17	UBA-30569
Sandeplan	Sus 240	Max.	2890	52	-20.9	8.1	3.15	UBA-30570
Sandeplan	Cervus 2088	Scap.	2839	44	-20.9	5.2	3.14	UBA-30571







# Diet, Toothache and Burial Diversity

Tracing Social Status through Bioarchaeological  
Methods in Late Neolithic–Early Bronze Age Scania

BY ANNA TORNBERG

## Abstract

*Scholars have long discussed social hierarchies associated with the Early Bronze Age in southern Scandinavia. In this paper, social hierarchies are targeted through bioarchaeological methods. Fifty new radiocarbon dates from 50 individuals show that there is an increase in burial complexity from the Early Late Neolithic to the Early Bronze Age. Further, stable isotopes of carbon and nitrogen were analysed in 29 of the individuals and dental caries were then assessed in a data set of 598 post-canine teeth, to examine differences in diet between individuals associated with different inhumation practices. The nitrogen values indicate that manuring was practised during the period, but there was no statistical difference in diet or dental caries between burials. It is argued that different types of burials are associated with different social levels in society, but that there is not a higher meat consumption or visibly different food behaviour among individuals interpreted as being a member of the “elite”.*

## Introduction

The Late Neolithic–Early Bronze Age of southern Scandinavia (c. 2300–1100 BC) spans over a period of a millennium or so. It is true that there is a distinct difference in material culture starting with Early Bronze Age period II (c. 1500 BC), but the periods predating this are often treated as homogeneous. Is homogeneity and shift in material culture also a homogeneity and shift in group identity? Recently, many new <sup>14</sup>C dates have been made on skeletal material dating from the Battle Axe Culture (BAC)

to Early Bronze Age, both within the project “The Rise” (Bergerbrant *et al* 2017) and within my own research. This gives the opportunity to study the use of Neolithic and Bronze Age burials in more detail.

The formation of Bronze Age society of Southern Scandinavia is often understood as a development of chiefdoms where political power was upheld through prestige items of the elite (Vandkilde & Northover 1996, 305 ff.; Kristiansen 1999; Kristiansen 2011; Earle *et al.* 2015). This power strategy is referred

to as network strategy (Kristiansen & Earle 2015). Sherratt (1997) argues that this kind of Bronze Age society has its foundation in the *Secondary Products Revolution* (SPR), where secondary products, such as milk and wool, increased in importance. The intensification of agricultural activities led to an economic surplus which allowed specialization and metal trade. The SPR would also allow a population increase, also considered to be a trigger for the development of hierarchical societies (Earle 1989). Skoglund (2009), however, provides evidence that the network strategy was not uniform in all of Southern Scandinavia during the Bronze Age, but rather occurred side by side with a corporate strategy. The corporate strategy is mostly associated with Neolithic societies. They are not primarily controlled by exchange of prestigious items but rather by reproduction of knowledge within all of the society. Kristiansen and Earle (2015) argue that the political systems differed between Neolithic and Bronze Age societies in that Neolithic political economies were based exclusively on local resources while politics during the Bronze Age were upheld through continuous trade with long-distance core areas. Skoglund suggests that the network strategy is probable in Scania and Denmark while the corporate strategy is applied further north. This, among other things, is demonstrated by the richly equipped barrows in the south not present further north. This is also suggested by Vandkilde and Northover (1996).

Social status could be demonstrated through prestige items, but also through diet. Food habits are closely connected to cultural settings and serves as more than just nutrition. These cultural differences might reflect differences in religion, taboos or social hierarchies. Isaksson (2000) found different dietary habits between peasants and the elite in the Vendel Period in Sweden, where meat was ranked as high-status food. Knipper *et al.* (2015), however, could not detect differences

in diet in deviant burials, thought to be those of non-locals, associated with the Early Bronze Age Únětice culture in central Germany (c. 2200–1700/1660 BC). The deviant burials could not be associated either with non-local  $^{87}\text{Sr}/^{86}\text{Sr}$  levels or a different diet than individuals buried in the more common type of Únětice burials. Dietary analyses based on stable isotopes could provide information about differences in diet related to, for instance, burials. Deviant burials of different sorts often intrigue archaeologists, leading to theories that these burials might relate to migrants or individuals of another social rank. However, relations between differences in burial practice and differences in diet seem to coincide only on a local scale. Le Bras-Goude *et al.* (2012) found some evidence for differences in diets between burial practices in the Languedoc region in France, possibly mirroring one pastoral and one agriculturalist group. Also Waterman *et al.* (2014) found differences in diets between several Neolithic and Copper Age sites in Portugal that could be expressions of social differentiation in consumption patterns. However, Giblin and Yerkes (2016) could not detect social hierarchization through dietary patterns in Copper Age Hungary.

In an ongoing study of stature based on 164 femora from South Swedish Middle-Late Neolithic, I conclude that there is an event of significantly increasing male statures in the Battle Axe Culture (BAC) in relation to the earlier period of Funnel Beaker Culture, and the partly contemporary Pitted Ware Culture. There might also be another event of increasing male stature between the early Late Neolithic (LNI) and the later Late Neolithic and Early Bronze Age (LNII–EBA), although not as significant as in the BAC (Tornberg in prep.). These changes in stature also correlate well with periods of migration and significant changes in material culture and social foundations, whereas stature remains more or less static

in times of more archaeological stability. Social changes, and possible changes in social status, are also reflected in human biology. In this paper I will examine bioarchaeological approaches to social stratification in the late part of the Late Neolithic and the Early Bronze Age. The questions to be examined are: is the heterogeneity in burial customs traditionally associated with the South Scandinavian Late Neolithic and Early Bronze Age (inhumations in flat graves, gallery graves and barrows) related to a difference in chronology, and are there differences in dietary isotope values between individuals buried in these different grave types that cannot be explained by chronology?

## Material and method

The material consists of radiocarbon dates of 50 individuals from the province of Scania, southernmost Sweden (Fig. 1). All dates span from Late Neolithic period I (LNI) to the Early Bronze Age period II–III (EBAII–III)

and are performed at the AMS radiocarbon laboratory the <sup>14</sup>Chrono Centre, Queen's University, Belfast and at the Department of Geology, Lund University. Radiocarbon dates have then been calibrated (2 sigma) using Oxcal online (Oxcal v. 4.2).

Twenty-nine of the individuals (n=29 samples) dated to LNII–EBAII have also been studied for dietary isotopes of  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  in collagen. The 29 individuals were selected based on stage of preservation, where individuals with lower jaws were primarily chosen, and to represent the three dominant burial practices during the South Swedish Late Neolithic and Early Bronze Age (flat earth graves, gallery graves and barrows).

The levels of the carbon and nitrogen isotopes largely reflect the protein contribution to the diet (Hedges & Reynard, 2007). The level of  $\delta^{13}\text{C}$  reflects whether the diet was based mainly on terrestrial or marine resources (Van der Merwe 1982; Schoeninger & DeNiro 1984), with levels lower than  $-20\text{‰}$  considered entirely terrestrial and



Fig. 1. The regions concerned in this paper. **A:** The Vellinge area (Kyhlibjersbacken, Vellinge 27, Håslöv); **B:** The Trelleborg and Österlen area (Abbekås, Snorthög, Bollerup, Ahlbäcksbacken); **C:** The Kristianstad area (Ångamöllan, Nosaby, Öllsjö); **D:** Rörbäck.

up to  $-12_{\text{‰}}$  as entirely marine in northern Europe (Eriksson & Lidén 2013). The levels of  $\delta^{15}\text{N}$  refer to the trophic level with an enrichment along the food chain commonly reported as about  $3_{\text{‰}}$ , animals preying on herbivores having values of about  $9_{\text{‰}}$  on land (e.g. Schoeninger & DeNiro 1984; Eriksson & Lidén 2013). However, O'Connell *et al.* (2012) measured an enrichment in collagen as high as  $6_{\text{‰}}$ , resulting in an overestimation of animal protein in past human populations. The marine ecosystem is somewhat different, allowing more trophic levels and therefore higher  $\delta^{15}\text{N}$  values (Schoeninger & DeNiro 1984). All analyses of dietary isotopes have been conducted at the  $^{14}\text{C}$  Chrono Centre in Belfast on individuals post-weaning. The collagen in the samples with a laboratory number below UBA-24991 was extracted through the modified Longin method developed by Brown *et al.* (1988) using a Vivaspin filter cleaning method (Bronk Ramsey *et al.* 2004) and an additional cleaning step where  $90\text{ }^{\circ}\text{C}$  water was used for pretreating ultra-filters. Further, samples with a laboratory number above UBA-24991 were pretreated using a simple ABA treatment followed by gelatinization and ultrafiltration with a Vivaspin filter cleaning method (Reimer *et al.* 2015). Samples have primarily been extracted from the mandible, but in one case a humerus and in three cases permanent teeth (one premolar, one lower first molar and one upper first molar) were used. The humerus was sampled on the distal diaphysis where bone is compact. Cortical bone was chosen for analysis since it is less likely to suffer from diagenetic change than trabecular bone. All mandibles and the humerus mirror the diet in the last ten years or so while the teeth reflect childhood diet (4–6 years for the first molar and 7–10 years for the premolar using Schour and Massler's dental development diagram available in Hillson 1996, 143). Even though it is possible that diet changes between childhood and

adulthood there is nothing in the examined material to suggest such a change.

The radiocarbon dates and dietary isotopes of  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  have then been statistically analysed using one-way analysis of variance (ANOVA) to test the null hypothesis that there is no difference in diet between burial traditions during the LNII and the Early Bronze Age. The test was conducted using the data analysis package in Microsoft Excel with a significance level of  $=0.05$ .

Since studies of dietary isotopes in collagen are poorly connected to the amount of carbohydrates ingested, additional studies of dental caries have been conducted. Dental caries is caused by acids produced by bacteria breaking down sugar. These acids can lead to the destruction of the enamel, dentine and tooth cementum, causing a cavity (Hillson 1996). There is a strong correlation between the amount of carbohydrates (especially sugars) and dental caries. There is evidence that caries frequencies increase in developing countries where the former dependence on starchy foods is replaced in part by refined sugars (Touger-Decker & van Loveren 2003). Gibson and Williams (1999) found a significant correlation between dental caries and the consumption of sugars in children living in Great Britain. However, they did not find a significant correlation between caries and other foods. The Swedish Vipeholm study, although conducted with ethically questionable methods, also found this correlation (Gustafson *et al.* 1954). The correlation between dental caries and starchy foods is complex. Modern examples show a low correlation between dental caries and carbohydrates other than refined sugar. However, there is a lack of dental caries among South Scandinavian hunter-gatherers, with increasing frequency in the Neolithic (Ahlström 2003). There are a number of similar observations all over the world (e.g. Cohen & Armelagos 1984; Wittwer-

Backofen & Tomo 2008). This suggests that there in fact is a correlation between dental caries and other carbohydrates than refined sugars in prehistoric societies.

Dental caries studies provide further insight into possible differences in diet not reflected by stable isotopes in collagen. Therefore, a total number of 598 post-canine teeth were included to evaluate dental caries frequencies. All teeth derive from the Scanian contexts that have been <sup>14</sup>C-dated to LNII and EBA included in this study, but not all teeth are associated with the individuals included in the stable isotope analysis. Dental caries was studied macroscopically under a bright light. Only cavities were recorded as present caries whereas opaque stains were recorded as absent. The location of caries was recorded

as 0=no caries detected, 1=occlusal surface, 2=interproximal surface, 3=smooth surface (buccal, labial, lingual), 4=cervical caries (not interproximal regions), 5=root caries, 6=large caries, 7=non-carious pulp exposure, 9=not observable, as suggested by Buikstra and Ubelaker (1994).

## The Late Neolithic – Bronze Age – burial traditions and complex identities

The radiocarbon dates of Late Neolithic and Early Bronze Age skeletons show that a typological dating of burials from this period is close to impossible. The burial tradition

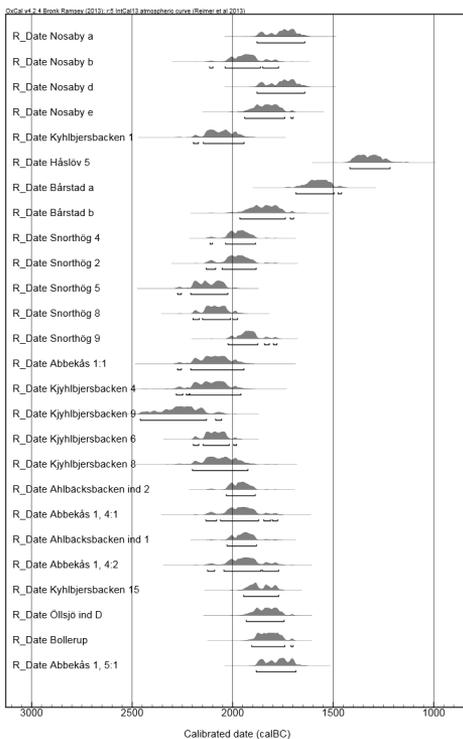
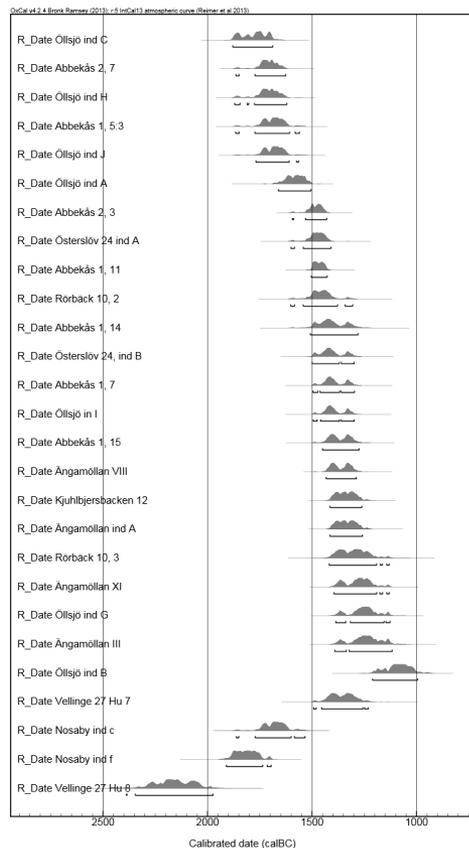


Fig. 2. Calibrated <sup>14</sup>C dates (cal BC) of Late Neolithic and Early Bronze Age graves in Scania. Calibration made using OxCal online.



seems to have been more complex than was previously thought. In this paper, these radiocarbon dates (Fig. 2) are provided and discussed in relation to social status.

The early part of the Late Neolithic seems to be an exception to the complexity inferred above. All of the graves (n=11) that have been dated to LNI (c. 2300–1950 BC) are inhumations in flat earth graves (Table I). Most graves hold only one inhumation, but there are also flat earth graves that have not yet been dated that include two or more inhumations. These might fall into the LNI span. There is a strong resemblance between burial customs in the early Late Neolithic and the pre-dating the Battle Axe Culture, regarding both burials in flat earth graves

and the common crouching position of the buried. This is the dominant grave position at the Scanian site of Snorthög in Lilla Isie parish (Fig. 3), where a grave field from the early and late Late Neolithic is situated underneath a Bronze Age barrow.

Around 2000 BC people in Scania started to construct gallery graves; but the majority of burials in Scanian gallery graves seem to be dated to the Early Bronze Age (Table II). Some of the gallery graves, such as the Öllsjö gallery grave, have been rebuilt from Middle Neolithic passage graves. However, the custom of burying the dead in flat earth graves continues (Table I). Differing from the flat earth graves in the earliest part of the Late Neolithic is the custom of burying more than one individual in the

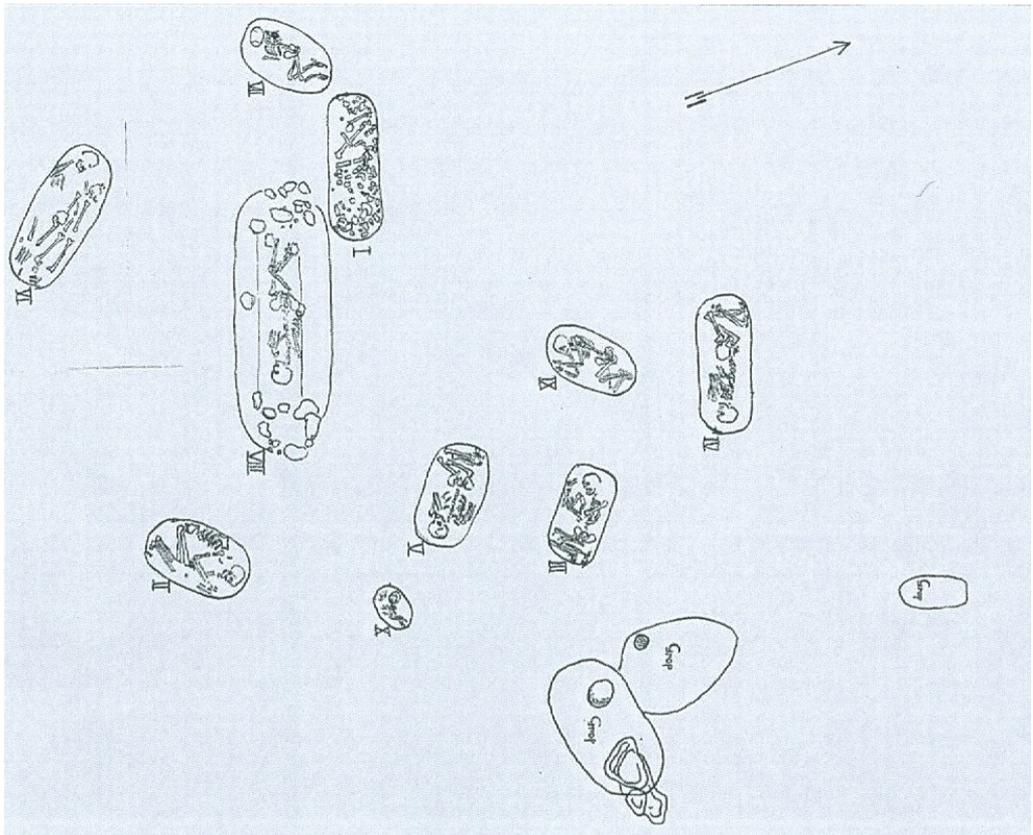


Fig. 3. The Late Neolithic burials of Snorthög, Lilla Isie parish.

Table I. Distribution of burial types in Late Neolithic-Early Bronze Age Scania, Southern Sweden. Radiocarbon dates made by Chrono laboratory, University of Belfast (UB and UBA) and the Department of Geology, Lund University (LuS). Dates are calibrated (2 sigma) using OxCal online.

LN I					
Locality	Burial Type	14C date BP	14C Date (cal.) BC	Lab no.	Sample material
Kyhlbjersbacken 9	Flat	3805 ± 53	2460-2056	UBA_24002	Bone
Snorthög 5	Flat	3726 ± 35	2275-2025	UB_22851	Bone
Kyhlbjersbacken 4	Flat	3715 ± 50	2196-1981	LuS 10621	Bone
Abbekås 1, 1	Flat	3700 ± 50	2275-1945	LuS 10618	Bone
Kyhlbjersbacken 6	Flat	3697 ± 28	2196-1981	UBA_24000	Bone
Snorthög 8	Flat	3694 ± 32	2198-1977	UB_22852	Bone
Kyhlbjersbacken 8	Flat	3675 ± 50	2201-1925	LuS 10622	Bone
Snorthög 2	Flat	3616 ± 41	2132-1884	UB_22850	Bone
Snorthög 4	Flat	3608 ± 32	2113-1887	UB_22849	Bone
Vellinge 27, Hu 8	Flat	3748 ± 58	2389-1974	UBA_30561	Tooth root
Kyhlbjersbacken 1	Flat	3675 ± 40	2196-1944	LuS 11853	Bone
LNII					
Locality	Burial Type	14C date BP	14C Date (cal.) BC	Lab no.	Sample material
Ahlbäcksbaken ind 2	Flat	3604 ± 30	2032-1889	UBA_24005	Bone
Abbekås 1, 4:1	Gallery grave	3600 ± 50	2134-1777	LuS 10619	Bone
Ahlbäcksbaken ind 1	Flat	3588 ± 30	2029-1882	UBA_24004	Bone
Abbekås 1, 4:2	Gallery grave	3585 ± 50	2125-1772	LuS 10620	Bone
Snorthög 9	Flat	3571 ± 32	2024-1780	UB_22853	Bone
Kyhlbjersbacken 15	Flat	3537 ± 28	1946-1771	UBA_24003	Bone
Öllsjö ind D	Gallery grave	3512 ± 35	1933-1745	UB_22855	Bone
Bollerup 4:1	Flat	3496 ± 32	1906-1700	UB_27863	Tooth root
Abbekås 1, 5:1	Flat?	3453 ± 35	1883-1686	UB_22837	Bone
Öllsjö ind C	Gallery grave	3453 ± 32	1880-1689	UB_22854	Bone
Nosaby ind f	Gallery grave	3491 ± 35	1910-1696	UBA_30560	Tooth root
Nosaby ind b	Gallery grave	3580 ± 45	2115-1772	LuS 11850	Bone
Nosaby ind e	Gallery grave	3510 ± 40	1941-1700	LuS 11852	Bone

EBA					
Locality	Burial Type	14C date BP	14C Date (cal.) BC	Lab no.	Sample material
Nosaby ind a	Gallery grave	3535 ± 40	1880-1642	LuS 11849	Bone
Nosaby ind d	Gallery grave	3435 ± 40	1880-1642	LuS 11851	Bone
Abbekås 2, 7*	Barrow	3410 ± 30	1865-1627	UBA_22992	Bone
Öllsjö ind H*	Gallery grave	3408 ± 34	1871-1622	UB_22846	Bone
Abbekås 1, 5:3*	Flat?	3387 ± 38	1866-1561	UB_22840	Bone
Öllsjö ind J	Gallery grave	3385 ± 35	1769-1565	UB_22845	Bone
Öllsjö ind A	Gallery grave	3308 ± 32	1662-1506	UB_22842	Bone
Österslöv 24 ind A	Gallery grave	3204 ± 36	1601-1410	UB_27865	Tooth root
Abbekås 1, 11	Barrow	3197 ± 21	1504-1428	UB_22836	Bone
Rörbäck 10, 2	Barrow	3180 ± 45	1603-1306	LuS 10623	Bone
Abbekås 1, 14	Barrow	3144 ± 49	1509-1281	UB_22835	Bone
Österslöv 24 ind B	Gallery grave	3140 ± 39	1500-1299	UB_27864	Tooth root
Abbekås 1, 7	Barrow	3131 ± 33	1496-1298	UB_22841	Bone
Öllsjö ind I	Gallery grave	3130 ± 31	1495-1299	UB_22844	Bone
Abbekås 1, 15	Barrow	3111 ± 35	1451-1271	UB_22838	Bone
Ängamöllan VIII	Gallery grave	3105 ± 29	1433-1289	UBA_23998	Bone
Kyhbjersbacken 12	Flat	3073 ± 28	1414-1263	UBA_24001	Bone
Ängamöllan ind A	Gallery grave	3070 ± 29	1415-1260	UBA_23997	Bone
Rörbäck 10, 3	Barrow	3045 ± 45	1419-1132	LuS 10624	Bone
Ängamöllan XI	Gallery grave	3025 ± 34	1396-1131	UBA_23999	Bone
Öllsjö ind G	Gallery grave	3011 ± 33	1387-1128	UB_22857	Bone
Ängamöllan III	Gallery grave	3004 ± 40	1392-1117	UBA_23996	Bone
Öllsjö ind B	Gallery grave	2899 ± 34	1211-996	UB_22843	Bone
Vellinge 27, Hu 7	Flat	3101 ± 46	1493-1232	UBA_30558	Bone
Nosaby ind c	Gallery grave	3381 ± 42	1863-1534	UBA_30559	Tooth root
Håslöv 5	Barrow	3060 ± 40	1418-1218	LuS 11854	Bone

The Flat? grave of Abbekås is referring to a grave with multiple burials outside a gallery grave.

\*Dates suggest either LNII or EBAI.

same grave (all except Snorthög grave IX and Bollerup 4:1), even though single burials also existed simultaneously.

During the Early Bronze Age, especially from period II (c. 1500–1300 BC), an additional burial practice was present, the characteristic barrow. During the Early Bronze Age the complexity of burial traditions seems to culminate. During this period individuals

are buried in flat earth graves (both single and multiple inhumations), in cairns, mounds and gallery graves. Most of the burials in the gallery graves actually date to the Bronze Age (68%) and not to the Late Neolithic (Table II). This differs from, for example, Västergötland in south-west Sweden, where only 29% of the gallery graves include Bronze Age burials at all (Blank 2016). Even though

Table II. Summary table of the frequency of the different burial types associated to the three studied periods.

	Flat earth	Barrow	Gallery grave
LNI	11	0	0
LNII	6	0	7
EBA	3	8	15

not present here, there are also possibilities of both Late Neolithic and Bronze Age reburials in passage graves. This is known from other parts of southern Sweden (Arne 1909; Blank 2016). The numbers of individuals from gallery graves and flat earth graves are fairly equal (20 and 22) whereas the number of individuals from mounds is only eight. This is a consequence of well-preserved skeletons from barrows not being as abundant as those from gallery graves and flat earth graves in this area. It seems as if the practice of inhumation in flat earth graves decreases while burials in gallery graves increase. There is no evidence of barrows being constructed earlier than in the EBA. The EBA spans over a larger time period than do LNI and LNII, and therefore a larger sample size is to be expected. However, the majority of burials derive from the first three hundred years, so the material might mirror a population increase during the period.

In the Late Bronze Age, the practice of cremating the dead dominated. However, cremations are known from both Middle and Late Neolithic contexts as well (Hansen 1937; Olausson 2015). No cremated remains have been integrated in this study, so there is a possibility that burial practices might have been even more complex than presented in this paper.

## Targeting social stratifications and identities through dietary studies

It is evident that there exists a complexity considering burial traditions during the late part of the Late Neolithic (after 2000 BC) and especially in the Early Bronze Age in south Sweden. It is true that burial goods classically interpreted as high-status goods, such as different types of bronzes, seem more abundant in barrows than in flat earth graves or gallery graves from the same period (Håkansson 1985; Olausson 1993). This might well mirror different social strata through material culture. However, this is somewhat difficult to study since systematic observations only are known from barrows and flat earth graves, considering the previous lack of knowledge that gallery graves also include Bronze Age burials to such a large extent. Differences in social and economic status could also be revealed through bioarchaeological studies of health and diet.

A total of 29 individuals from the LNII and EBA were analysed for  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  to evaluate diet (Table III). All samples included had a C:N ratio between 2.9 and 3.5 as generally recommended (e.g. DeNiro 1985; van Klinken 1999). The range of the sample is -19–24.5‰ for  $\delta^{13}\text{C}$  and 8.14–11.3‰ for  $\delta^{15}\text{N}$ . The mean of the  $\delta^{13}\text{C}$  is -20.78‰ with a standard deviation of 1.29 and the mean of the  $\delta^{15}\text{N}$  is 9.73‰ with a standard deviation of 0.76. The  $\delta^{15}\text{N}$  mean value of 9.73‰ shows that these individuals were high up in the food web.

To evaluate whether there is a significant difference in diet between individuals inhumed in different burial types, one-way analysis of variance (ANOVA) was applied. The null hypothesis is that there is no difference in  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values associated with burial custom. The sample of 29 individuals was distributed as in table IV.

Table III. The results of the stable isotope analysis. One sample was excluded from analysis since it did not fall within the recommended C:N range of 2.9-3.5.

Skeleton	$\delta^{13}\text{C}$ (‰)	C At%	$\delta^{15}\text{N}$ (‰)	N At%	C:N ratio	Yield
Snorthög 9	-24.5	24.70	8.91	8.80	3.27	11.7000
Abbekås 1, 5:1	-19.97	14.75	10.14	5.30	3.24	35.1000
Abbekås 1, 5:3	-21.2	12.75	9.44	4.65	3.21	19.6000
Abbekås 1, 15	-19.62	14.45	10.15	5.10	3.31	12.2000
Abbekås 1, 14	-19.89	12.30	10.38	4.40	3.24	26.8000
Abbekås 1, 7	-19.2	9.55	9.28	3.25	3.43	14.2000
Abbekås 1, 11	-20.87	11.70	9.28	4.20	3.25	20.9000
Öllsjö A	-22.2	7.80	8.14	2.60	3.47	15.9000
Öllsjö B	-23.5	7.25	9.57	2.35	3.55	15.0000
Öllsjö C	-22.5	24.60	8.75	8.95	3.20	11.8000
Öllsjö D	-19	37.15	9.22	13.50	3.22	2.4000
Öllsjö G	-22.2	13.05	9.73	4.50	3.35	4.4000
Öllsjö H	-21.4	20.75	9.39	7.55	3.20	13.5000
Öllsjö I	-21.9	16.25	8.24	5.70	3.33	9.4000
Öllsjö J	-23.5	32.35	9.12	11.40	3.31	1.9000
Abbekås 2, 7	-19.3	na	10.5	na	3.16	8.00
Ängamöllan 3	-20.4	na	9.5	na	3.30	3.30
Ängamöllan A	-20.1	na	10.1	na	3.22	0.90
Ängamöllan VIII	-19.8	na	9.9	na	3.22	1.20
Ängamöllan XI	-20.8	na	8.9	na	3.31	0.00
Kyhlibjersbacken 12	-19.9	na	11.3	na	3.17	5.10
Kyhlibjersbacken 15	-20.7	na	10.2	na	3.21	4.30
Ahlbäcksbacken 1	-21	na	9.9	na	3.29	13.90
Ahlbäcksbacken 2	-20.6	na	10	na	3.23	4.30
Nosaby ind. F	-19.8	na	10.7	na	3.17	15.40
Nosaby ind. C	-19.8	na	10.1	na	3.17	11.30
Vellinge 27, Hu 7	-20.4	na	10.8	na	3.45	10.90
Bollerup 4	-19.9	na	10.5	na	3.19	5.90
Österslöv 24, ind. a	-21.5	na	9.1	na	3.40	7.50
Österslöv 24, ind. b	-20.6	na	10.4	na	3.27	1.00

The ANOVA analysis showed that there is no statistical difference in either  $\delta^{13}\text{C}$  or  $\delta^{15}\text{N}$  values between individuals associated with different burials (Table V). The null hypothesis was therefore proven correct. The proportion of marine and terrestrial dietary reliance does not differ in any significant way

between different burial traditions, nor does the proportion of meat consumption. Even though there is a difference in mean values between all burial types, the difference is not statistically significant. The gallery graves show the lowest  $\delta^{15}\text{N}$  values and flat earth graves the highest, with barrows in between.

Table IV. The distribution of the sample. Isotope values are presented as mean values, standard deviations (SD) and coefficient of variation (CV %).

	Flat earth	Barrow	Gallery grave
$\delta^{13}\text{C}$ (‰)	-20.91	-19.78	-21.03
SD	1.4276	0.6694	1.2613
CV%	6.8	3.4	6
$\delta^{15}\text{N}$ (‰)	10.13	9.92	9.42
SD	0.7066	0.5958	0.7483
CV%	6.8	6	7.9
No. ind.	9	5	15

Note that these values do not correspond to the  $\delta^{13}\text{C}$  values, that is, the highest  $\delta^{15}\text{N}$  values do not correspond to the highest (least negative)  $\delta^{13}\text{C}$  values reflecting a larger marine input. The isotopic values in the gallery graves, however, correlate well with each other, a high  $\delta^{13}\text{C}$  value and a lower  $\delta^{15}\text{N}$  value.

Since stable isotopes of collagen mainly reflect the protein contribution to the diet, dental caries was studied to reflect whether there was a high or low amount of carbohydrates in the diet. The percentage of

Table V. Statistics of the ANOVA showing no statistic difference in  $\delta^{13}\text{C}$  values or  $\delta^{15}\text{N}$  values between burial type in the LNII and EBA in Scania.

	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$
<i>F</i>	1,980267	2,813493
<i>F</i> -crit	3,369016	3,369016
<i>p</i> -value	0,15831	0,078325

dental caries differs between the burial types, especially between gallery graves and barrows. Gallery graves have the lowest percentage of dental caries (4.2% of 397 teeth), followed by flat earth graves (6% of 124 teeth). Barrows show the highest frequency with 9% of 109 teeth being affected (Table VI). Teeth are at unequal risk of developing dental caries. Incisors and canines are less frequently carious than are premolars and molars. To avoid bias in caries frequency due to this unevenness in risk, only post-canine teeth (premolars and

Table VI. The amount of dental caries in Scanian burials dated to LNII-EBA.

	Flat earth	Barrow	Gallery	Total
No. teeth	117	100	381	598
No. Caries	7	9	16	32
%	6	9	4.2	5.4

Table VII. Results of the Fisher's Exact Test for Count Data of dental caries. The differences in caries frequencies are not statistically significant and could be due to sampling strategies. A=Flat earth, B=Barrows, C=Gallery graves.

	A-B		A-C		B-C	
	A	B	A	C	B	C
Observed	7	9	7	16	9	16
Total	117	100	117	381	100	381
<i>p</i> -value	0.4499		0.4552		0.0818	
Odds ratio	1.5016		0.7024		0.4674	

molars) were selected for analysis. However, there are some differences in risk between post-canine teeth as well, possibly skewing the results if the representation is vastly different between burial types. Teeth with very severe caries or heavy attrition, leading to ante-mortem tooth loss, could not be included in this study, and could also bias the results somewhat. The amount of these types of teeth might also be unevenly distributed between different burial types, although there are no such indications visible in the data.

To sort out whether differences in dental caries were significant or could be a matter of sampling issues, Fisher's Exact Test for Counting was used. The test was conducted using the free statistical software R (r-project.org). The test is more restrictive than a traditional chi-squared test and not as sensitive to bias when dealing with small samples. According to the test, the differences in dental caries between different burial traditions were not statistically significant and could be the result of sampling strategies (Table VII). The largest difference in dental caries between gallery graves and barrows had a *p*-value of 0.0818. Therefore, it cannot be proven that there is heterogeneity in dental caries frequencies associated with burial tradition.

## Discussion

It is evident that there is an increasing diversity and complexity in burial tradition from the early part of the Late Neolithic to the Early Bronze Age period II in Scania, southernmost Sweden. The burial tradition of the Middle Neolithic B, the Swedish-Norwegian Battle Axe Culture, seems to expand into the Early Late Neolithic. Flat earth graves, mainly single graves, dominate in the archaeological record, at least in Scania. Gallery graves were not constructed until around 2000 BC. These

graves with multiple inhumations coexisted with single and multiple inhumations in flat earth graves. In the Early Bronze Age an additional burial type, the barrow, came into use. The increase in burial complexity could reflect an increase in social stratification or differences in group identities. Visible differences between social groups become important to upheld power. To investigate whether there were differences in dietary isotopes related to differences in burial tradition, a statistical analysis of ANOVA was applied. Diet was further analysed through the frequencies of dental caries, known to correlate with the amount of ingested carbohydrates.

The ANOVA showed that there was no significant difference in either  $\delta^{13}\text{C}$  or  $\delta^{15}\text{N}$ . The  $\delta^{15}\text{N}$  values were somewhat lower and  $\delta^{13}\text{C}$  somewhat more negative in collective graves (i.e. gallery graves) than in flat earth graves and barrows, where individual inhumations were present, although both in single graves and in graves with multiple burials this might be the effect of sampling issues. The  $\delta^{15}\text{N}$  values are generally high, with a mean value of 9.73‰. As high values might indicate that manuring was practised in Scania during the Late Neolithic (Bogaard *et al.* 2007; 2013). The analysis of dental caries showed that there were some differences in frequencies, but none were statistically significant. The difference in mean values between gallery graves with the lowest amount of dental caries and barrows with the highest amount had a *p*-value of 0.0818 (significance at *p*=0.05). Since differences in caries frequencies are not statistically significant it is possible that dental caries is a poor indicator of ingested carbohydrates or that the amount of carbohydrates in the diet is homogeneous between individuals associated with different burial practice.

Apel (2005) thinks that the distribution of flint production places in relation to the finding places of flint daggers indicates a

complexity and specialization during the Late Neolithic and Early Bronze Age. These centres are not at the same location. Further he suggests that complexity also is associated with a higher degree of division of labour. Increased division of labour is also necessary for a hierarchization of society. Different scholars argue that the introduction and distribution of metal are catalysts for this hierarchization process and therefore put it in the EBAIb or EBAlI (Vandkilde & Northover 1996; Kristiansen 1999; Earle 2002). However, Apel (2001; 2005) argues that this process began already in the LN and was connected to the distribution of flint daggers.

The bioarchaeological evidence reflects tendencies more in favour of the latter, although towards the later parts of the period. There are changes in burial tradition starting with the BAC where a predominance of flat earth graves is evident. This change is consistent through LNI. This indicates that there is no difference in social hierarchy or group identity during the Early Late Neolithic, at least none that is reflected in the burial tradition. Further, studies of stature in Neolithic and Bronze Age southern Sweden show that there is an event of increasing male statures in the BAC that stays consistent throughout LNI (Tornberg in prep.). This might be related to changes in social settings and a higher degree of specialization already during the BAC; however, I argue that a more developed social stratification did not exist until later. Artursson (2005) argues that there was an increase in hierarchies beginning in LNI and culminating in EBAlI, reflected in the variation in longhouse sizes. He also argues that there are tendencies for centre-periphery in south-western Sweden and in Zealand and Jutland already during the LNI. There are clusters of houses of various sizes, forming village-like settlements, in areas abundant in flint, where only scattered houses are present in more peripheral areas

(Artursson 2005; Brink 2013). This gradual increase in social stratification is also reflected in the burial tradition showing a gradual increase in burial diversity, starting around 2000 BC, culminating in EBA II. This corresponds to events in central Europe where bronze production seems to have increased dramatically around 2000 BC (Vandkilde 2007, 95).

Håkansson (1985) concludes that it is probable that the differences in burial practice during the EBA in fact reflect differences in social status, and that the central grave in a barrow is the most prominent, followed by other burials in barrows, flat earth burials and lastly gallery graves. This assumption is further strengthened by the idea of the elite manifesting its power through individual and monumental burials while peasants rather depended on the collective for survival and social foundation. If the individuals in barrows represent higher social rank it is possible that a somewhat increased dental caries frequency is due to the ingestion of honey. The exploitation of the honeybee is known already from Early Neolithic contexts in continental Europe (Roffet-Salque *et al.* 2015) and it was used in southern Scandinavia during the Bronze Age. A honey-sweetened drink is known from the Early Bronze Age burial from Egtved, Denmark (Denmark National Museum). Drinking alcoholic beverages could be associated with some sort of feasting or ritual drinking among the elites. The feasting could have been a strategy to uphold power (Bradley 1984, 64).

This study confirms an increasing social stratification from at least LNII, with a culmination in EBAlI. There is an increase in burial complexity throughout the Late Neolithic into the Early Bronze Age. It is probable that the increase in stature during the LNII–EBAlI is also connected to this change in society. However, no difference in stature between different burial types

during this period is evident, and therefore differences in health between different social status cannot be inferred (Tornberg, in prep.). It should also be stated that increasing stature also could be due to migrations, although this too is connected to the complex dawning society. There is no evidence of dietary diversity that could be associated with social status. Social stratification that is evident in the archaeological material does not show in the dietary record. It is possible that the view of the elite being more reliant on meat is not correct, and thus it is not reflected in the stable isotopes. If significant differences in the amount of dental caries could only be inferred when high amounts of refined sugar are ingested in modern examples, it might not be expected that a significant difference would be present between burial types in the Late Neolithic and Early Bronze Age. The caries frequencies still add to a low to moderate level.

## Conclusion

It is evident that burial complexity increases from the early part of the Late Neolithic to the Early Bronze Age. New radiocarbon dates on individuals in graves that have previously only been typologically dated show that there were many burial traditions simultaneously in the province of Scania, especially during the Early Bronze Age. It is concluded that gallery graves were constructed after 2000 BC and used for a long period of time, at least into the EBA. The majority of the radiocarbon dates of gallery graves suggest Bronze Age burials. The diversity in burial practice is interpreted as coinciding with an increase in social diversity and a more hierarchic society where visible differences between the “elite” and “commoners” become important to upheld power.

The ANOVA show that there is no significant difference in diet associated with burial tradition. There are small differences in

caries frequencies between the burial types, the difference between gallery graves and barrows being the largest, although not statistically significant. It is possible that traditional thoughts of high meat consumption among the “elite” are not valid during the Late Neolithic and Early Bronze Age. High values of  $\delta^{15}\text{N}$ , however, imply that manuring was practised in Scania during the Late Neolithic and Early Bronze Age.

## Acknowledgement

I wish to thank the Ebbe Kock and Berit Wallenberg foundations for generous financial contributions for radiocarbon dates included in this study. I would also like to thank the Ebbe Kock foundation, Kungliga fysiografiska sällskapet in Lund and Stiftelsen fil. dr. Uno Otterstedts fond for generously financing analyses of stable isotopes for diet reconstructions.

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# Paper II







Contents lists available at ScienceDirect

## Journal of Archaeological Science: Reports

journal homepage: [www.elsevier.com/locate/jasrep](http://www.elsevier.com/locate/jasrep)

## Stature and the Neolithic transition– Skeletal evidence from southern Sweden

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## ARTICLE INFO

**Keywords:**  
Stature  
Maximum femur length  
Kruskal-Wallis  
Early Bronze Age  
Iterative discriminant analysis  
Neolithic

## ABSTRACT

Human stature is a variable often used to study health changes in present and past populations. In this study possible differences in stature from the late Mesolithic-Early Bronze Age, based on skeletal data from southern Sweden, are investigated. The sample comprises  $n = 203$  femora where maximum lengths were evaluated using non-parametric testing. Sex was assessed primarily using criteria on the pelvis and secondarily through statistical testing of sexual dimorphism. Measurements of the vertical diameter of the femoral head, femoral anterior-posterior and medial-lateral were evaluated using an *iterative discriminant analysis*. Results confirm a significant difference in femoral length between archaeological culture groups for both sexes. Male femoral lengths evidence a significant increase in the Battle Axe Culture that remained high throughout the Late Neolithic and Early Bronze Age. Only a minor increase in male stature associated with the transition to agriculture could be noticed; stature then remained constant until the Pitted Ware Culture. There was no change in female stature following the Neolithic transition. Female stature then increased gradually throughout the Neolithic, but decreased somewhat in the later part of the Late Neolithic-Early Bronze Age. These findings suggest that the transition to agriculture did not affect health in any profound way, and that the high stature in the BAC-Early Bronze Age are dependent on a mix of genetic influx, population increase and good nutrition and health, possibly linked to an intensification and consolidation of the agro-pastoral economy.

## 1. Introduction

The transition to agriculture is probably the most intensely investigated area within archaeology. The term Neolithic Revolution, first expressed by V. Gordon Childe, is largely abandoned among scholars today, but it emphasizes the importance of this transition to human society. The transition to agriculture must be understood on a regional basis, since both when the Neolithic transition occurred and how the custom of agriculture was adopted differ between areas. A short introduction of the Neolithic transition and Neolithic cultures in southern Sweden is therefore required. The introduction does not seek to be comprehensive, but to give an overview of current understandings of these cultures.

The Late Mesolithic in southern Scandinavia is associated with the Ertebølle Culture (c. 5200–4000 BCE). The site of Skateholm in southernmost Sweden contains a large variety of species, dominated by mammals; especially wild boar, red deer, roe deer and grey seal; and fishes, especially pike and perch (Jonsson, 1988), reflecting a wide dietary source. Findings of large refuse deposits of mollusk shells, i.e. *kitchenmiddens* (kökkenmödding) also evidence that mollusks were part of the diet. The archaeological findings are also supported by stable

isotope studies (Eriksson and Lidén, 2003; Eriksson and Lidén, 2013). For more details of the Skateholm burial and settlement site as well as the Ertebølle Culture the reader is recommended the work of Larsson (1984, 1988).

Sørensen and Karg (2014) set the Neolithic transition in Southern Scandinavia to 4000–3700 BCE, using  $^{14}\text{C}$ -dates. The debate among scholars has been whether agriculture was spread through migrations (Sørensen, 2014; Skoglund et al., 2012) or local adoption (Zvelebil, 1996; Price, 2000; Melchior et al., 2010) and is still somewhat inconclusive. The Early Neolithic is characterized by the material culture associated with the Funnel Beaker Culture (Trichtenbecher Kultur, TRB), which lasted until the Middle Neolithic A (Fig. 1). The subsistence was agriculture with remaining dependence on foraging strategies, at least in the beginning (Sørensen, 2014). Burial practice transformed from flat grave burials and burials in long barrows and dolmens in the Early Neolithic, to passage graves in the Middle Neolithic. The skeletal material is sparse from the Early Neolithic; the majority of TRB skeletons are retrieved from Middle Neolithic passage graves containing multiple inhumations.

The Pitted Ware Culture (PWC) (c. 3200–2300 BCE) was partly contemporary to the TRB. The people of the Swedish Pitted Ware

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<http://dx.doi.org/10.1016/j.jasrep.2017.10.031>

Received 9 February 2017; Received in revised form 9 October 2017; Accepted 22 October 2017

Available online 07 November 2017

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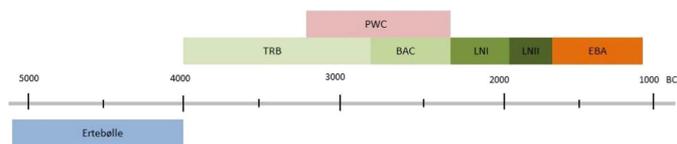


Fig. 1. Timeline over the late Mesolithic and the Neolithic–Early Bronze Age cultures in relation to chronology. Mesolithic: Ertebølle, Neolithic: TRB = Funnelbeaker Culture; PWC = Pitted Ware Culture; BAC = Battle Axe Culture; LNI = Late Neolithic I; LNII = Late Neolithic II; EBA = Early Bronze Age.

Culture lived in coastal areas, mainly on the east coast. These people were buried in flat graves and express an isotopic signal consistent with a marine diet dominated by seals (Eriksson, 2004; Fornander et al., 2008; Eriksson and Lidén, 2013). This is also consistent with the zooarchaeological record, where however pigs also are frequent (Storå, 2001). It is not definitely concluded if the pig bone assemblages common on several sites are from wild or domestic animals. However, Rowley-Conwy and Storå (1997) argue that they are wild which is also supported by stable isotopes (Fornander et al., 2008).

The Swedish–Norwegian Battle Axe Culture (c. 2800–2300 BCE) is part of the Corded Ware complex that was present in large parts of continental Europe. The BAC differs significantly from the preceding TRB and the partly contemporary PWC in cultural expression. People of the BAC were most commonly buried in flexed positions in single or double graves, with more or less strict schemes regarding body orientation and grave goods associated with the sex of the buried (Malmer, 1962; Olsson, 2015). There has been a scholarly debate considering whether the Corded Ware complex is due to migration from the Yamnaya in the east or due to local change in identity (Malmer, 1962; Malmer et al., 1986; Kristiansen, 1989; Damm, 1991; Fokkens, 1998). Recent studies of ancient DNA support the migration theory (Haak et al., 2015; Allentoft et al., 2015), even though it is uncertain to what extent.

The beginning of the Late Neolithic is set around 2300 BCE. Helle Vandkilde defined two phases of the Late Neolithic: The Late Neolithic I (c. 2350–1950 BCE) and the Late Neolithic II (c. 1950–1750 BCE), which she based on investigations of early metalwork in Denmark (Vandkilde, 1996). Much of the archaeological expressions of the early part of the Late Neolithic (LNI) resemble that of the late part of the BAC with settlements with one or a few long houses and flat grave burials in crouched or outstretched position. Radiocarbon dates suggest that inhumations in collective gallery graves got in use around 2000 BCE in Scania, southernmost Sweden, and Västergötland, southwestern Sweden, corresponding to the LNII. Inhumations in flat graves and reuse of Middle Neolithic passage graves were however still practiced (Blank, 2016). There is no evident difference in burial customs between the Late Neolithic and Early Bronze Age (EBA) until EBA period II (c. 1500–1300 BCE), when numerous burial mounds were erected. There was an increase in societal complexity during the Late Neolithic (Apel, 2001; Brink, 2013), leading to the onset of the Bronze Age around 1700 BCE. This can also be detected through an increased diversity in burial practice, culminating in the EBA period II (Tornberg, 2017). Some scholars argue that a hierarchical society is present in southern Scandinavia already in the Late Neolithic (Apel, 2001; Artursson, 2005; Brink, 2013) while others relate a hierarchical society to metal trade and thus put it in the EBA period Ib or EBA period II (Vandkilde, 1996; Kristiansen, 1999; Earle, 2002; Kristiansen and Earle, 2015). What is to be considered unanimously agreed among scholars is that there is a transition from an egalitarian society in the earlier parts of the Neolithic to a socially stratified, and more complex, society in the Late Neolithic or Early Bronze Age.

Ever since the contributors to the almost classic anthology “Paleopathology at the Origins of Agriculture”, edited by Cohen and Armelagos (1984), reported trends of decreasing health following the Neolithic transition in many parts of the world, discussions about the consequences of early agro-pastoralism on health have been heavily researched. This publication was followed up by the volume “Ancient

Health” about twenty years later (Cohen and Crane-Kramer, 2007). In this book, researchers of Neolithic health worldwide contributed to a more detailed and a somewhat more heterogeneous picture of health following the agricultural transition. For the Old World, a decline in health, based on a number of different types of health data, is mainly reported from South and Central Europe (Eshed et al., 2010; Larsen, 2006; Meiklejohn and Babb, 2011; Meiklejohn et al., 1984; Mummt et al., 2011; Wittwer-Backofen and Tomo, 2008). In the more peripheral regions of Scandinavia and the British Isles data supports an increase in stature, rather indicating an improvement in health in the Neolithic (Bennike, 1985; Bennike et al., 2007; Roberts and Cox, 2007). This is probably due to a more gradual adoption of farming in northern Europe than in the central and southern parts (Zvelebil, 1996).

Data from continental Europe suggests an increase in stature within the Neolithic, culminating in the Late Neolithic or Bronze Age (Meiklejohn et al., 1984; Bruchhaus, 2001; Gerhards, 2005; Gerhards, 2006). The trend is however not conclusive with Wittwer-Backofen and Tomo (2008) suggesting a further decrease of male stature in the Late Neolithic, although with an increase in stature in the female sample. Considerations have to be made to the relatively small sample size of nine individuals respectively in the male and female Late Neolithic sample. Earlier research of Late Neolithic health in southern Scandinavia reports an increase in stature compared to earlier periods of the Neolithic, with mean stature of 176–178 cm for males and 162–163 cm for females in Denmark (Arcini and Hyll, 2003; Bennike, 1985; Gejvall, 1963; Sjøvold, 1974; Tornberg, 2013; Tornberg, 2015). The studies are based on Danish skeletons ( $n = 66$ ) (Bennike, 1985) as well as a gallery grave from Dragby ( $n = 21$ ) (Gejvall, 1963) in central Sweden, a few individuals from Scania ( $n = 18$ ) (Tornberg, 2013; Tornberg, 2015), as well as a study of Middle Neolithic Hunter-Gatherers from the island of Gotland ( $n = 64$ ) (Sjøvold, 1974). There is however a lack of further research of Neolithic stature in southern Sweden as well as a synthesis related to stature and society. Previous research of Neolithic stature only comprises a low number of data, especially from the earlier periods. The data is also gathered from contexts that only have been dated in a relative sense, and as a consequence more detailed analyses of increasing stature during the Neolithic and Early Bronze Age cannot be made. A large number of  $^{14}\text{C}$ -datings from Scania, southernmost Sweden, suggest that it is problematic to date buried skeletons only from burial typology since Bronze Age reburials in Late Neolithic gallery graves have been practiced in very large extent (Bergerbrant et al., 2017; Tornberg, 2017). Considering earlier reports of high stature in the Late Neolithic in Denmark and parts of southern Sweden, this is also expected in this study. However, since previous studies of Late Neolithic stature in southern Sweden only comprise small samples, further analyses are needed. There is also little understanding of the development of stature within the Neolithic in southern Sweden as well as the effect on stature following the transition to agriculture. By including new stature data from all of the Neolithic, and a large amount of radiocarbon dates on Late Neolithic–Early Bronze Age skeletons, the development of stature throughout the Neolithic can be investigated.

In this study south Swedish Late Mesolithic, Neolithic, and Early Bronze Age stature has been recorded and analysed. I explore stature change following the transition to agriculture and throughout the Neolithic. Is there a change in stature following the transition to agriculture, and does Late Neolithic stature in southern Sweden equal as high as those reported from Denmark? In what way have male and

female stature developed from the Mesolithic to the Early Bronze Age in southern Sweden?

## 2. Materials and methods

Analyses of stature in this paper are based on measurements of the maximum length of the femur (Martin 1) (Martin and Saller, 1957). When referred to stature, maximum femoral length is referred, throughout the paper. Calculated stature is referred to as living stature. All measurements were taken on femoral bones with fused proximal and distal epiphyses to guarantee completed growth. Primarily, the left femur was chosen, with the right femur included only when the left femur was missing or not measurable due to fragmentation. A digital caliper with an accuracy of 0.03 mm and an osteometric board were used. All measurements have been rounded to the closest two decimals. When referring to calculated living stature the method of Sjøvold (1990) has been considered. This method is based on organic correlation from a range of different populations generally neutralising ethnicity, instead of least square regression formulae calculated from modern populations as is the case for Trotter and Gleser (1952). Sjøvold's method is known to not under-estimate tall individuals or over-estimate short individuals, which is considered beneficial for this investigation. Methods based on least square regression of modern population might also be biased by secular trend e.g. difference in mean stature in a population from one generation to another, where bones of the lower limb is longer in relation to stature than bones not affected by secular trend (Stinson, 2012). It is acknowledged that the most accurate method to estimate stature is to measure the skeleton in the grave (Boldsen, 1984; Petersen, 2005) or by the anatomical method (Fully, 1956; Fully and Pineau, 1960). This has not been possible due to the nature of the material, being commingled, fragmented and to a large extent recovered in the early 1900s.

The material integrated in this study consists of both new osteological investigations and previously analysed and published data. The complete sample comprises  $n = 203$  femora from multiple localities from the provinces of Scania in southernmost Sweden and Västergötland in south-western Sweden, one locality each from Uppland in central Sweden, Östergötland in south-eastern Sweden and the island of Öland, and from multiple localities on the island of Gotland (Fig. 2). The primary material is dated to the Late Neolithic-Early Bronze Age period II and consists of femora from  $n = 36$  individuals. A majority of this material ( $n = 30$ ) has been dated through AMS  $^{14}\text{C}$ , and remaining material have been dated only by typological characteristics on the grave goods. The AMS  $^{14}\text{C}$ -dating was carried out by  $^{14}\text{C}$  Chrono laboratory, Queens University, Belfast, the University of Oxford and by the Department of Geology, Lund University and calibrated using Oxcal online (Oxcal v. 4.2) (supplementary information). Additional analyses of Middle Neolithic agro-pastoralists from Västergötland (Wetterlinggården and Lockegården), associated with Funnelbeaker culture (TRB) and from Scania (Vellinge, Viby 26 and Lilla Bedinge grave 53) associated with the Swedish-Norwegian Battle Axe Culture (BAC), were also included. These remains have been dated through typological characteristics of burial type without additional  $^{14}\text{C}$  analyses. The remaining femoral data was not analysed in relation to this specific study. The complete sample with references is presented in Table 1. The TRB sample comprises femora from  $n = 60$  individuals. The osteological material from the Swedish-Norwegian Battle Axe Culture is generally not very well preserved, but  $n = 11$  measurable femora could be integrated in this study. This is a significantly larger dataset than present in Danish studies ( $n = 3$ ) (Bennike, 1985). In addition Late Mesolithic hunter-gatherers from Scania ( $n = 55$ ) and Middle Neolithic hunter-gatherers from the island of Gotland ( $n = 41$ ) were included in the analysis.

Since many of the Middle-Late Neolithic femora derive from graves with multiple inhumations, sex estimations using traditional criteria of the pelvis (Buikstra et al., 1994) has only been applicable on  $n = 16$

individuals from the Late Neolithic-Early Bronze Age (nine males and seven females) and  $n = 37$  individuals from the TRB (eight males and 29 females). The Late Neolithic-Early Bronze Age individuals have been sexed by the author and the individuals associated with the TRB have been analysed by Torbjörn Ahlström (personal communication). Remaining individuals have been assessed to sex using an Iterative Discrimination Analysis (I.D.A.) as suggested by van Vark (1974). The discriminant analysis was run on TRB and LN-EBA datasets separately. The analysis is based on measurements of the femoral anterior-posterior (Martin 10), medial-lateral (Martin 9) and vertical diameter of the femoral head (Martin 18) (Martin and Saller, 1957). The sex estimates are based on statistical modeling on samples of known sex from the same context where phenotype is similar. The results do not get biased through comparisons to modern data where body proportions might be different. However, the method might misclassify sex in the middle range since the iteration continues until all femora have been classified to either sex. This has, however, been proven to be a small problem in practice as long as the discriminatory factor is fairly large (van Vark, 1974, pp. 78 f.). Missing values have been imputed using an iterative regression, which is considered as good as, or better, than other missing data approaches (Holt and Benfer, 2000). Replacement of missing values with sample means would decrease the variability and probably increase sample bias. The regression has been carried out using the VIM package in the free statistical software R (Templ et al., 2011a; Templ et al., 2011b).

## 3. Results

There is only a slight increase in stature between the Ertebølle and the Funnelbeaker Culture for males. Female stature remains at the same level (Table 2). The stature is quite consistent with those reported for Mesolithic Denmark (Bennike, 1985). Bennike however, reports a male living stature increase of c. 8 cm between the Mesolithic and Middle Neolithic while current data only supports an increase of c. 2.5 cm. The data does not support any marked difference in stature related to the transition to agriculture in southern Sweden. There is a noticeable increase in male stature between the Middle Neolithic farmers associated to the Funnelbeaker Culture and the later farmers/agro-pastoralists of the Battle Axe Culture.

Male stature then remains more or less static from the BAC through the LN-EBA. The highest stature for both males and females are recorded in the LNI sample ( $n = 12$ ).

The lowest male living stature is recorded in the Ertebølle, but stature remains more or less the same from the Mesolithic until the Battle Axe Culture. That stature is consistent despite assumed different subsistence is of great interest and might reflect that nutrition and health quality did not differ in any substantial way in the earlier periods under study. Female stature on the other hand seems to increase more evenly throughout the whole Neolithic-Early Bronze Age; however remaining unchanged at the transition to agriculture and decreasing somewhat in the latest period. The lowest female mean stature is recorded in the Ertebølle and TRB. People of the Pitted Ware Culture are considered foragers (Rowley-Conwy and Storå, 1997; Eriksson, 2004; Fornander et al., 2008; Eriksson and Lidén, 2013), despite the Neolithic date, and could therefore not be directly compared to the farmers and agro-pastoralists. Male and female femoral lengths however indicate living statures more equal to those of the farmers of the TRB and the Mesolithic Ertebølle period rather than those of later periods. Median and mean maximum femoral lengths do not differ in any noticeable way (Table 3). The inclusion of median lengths is however important since it reduces the importance of outliers in small samples.

To visualize differences in femoral length, all samples and sub-samples were plotted in a boxplot (Fig. 3). The plot views median values and the box enclosures 50% of the data. Outliers are marked with circles. A clear difference in male femoral length is noted between Ertebølle-PWC and BAC-EBA. It is also noticeable that the median female

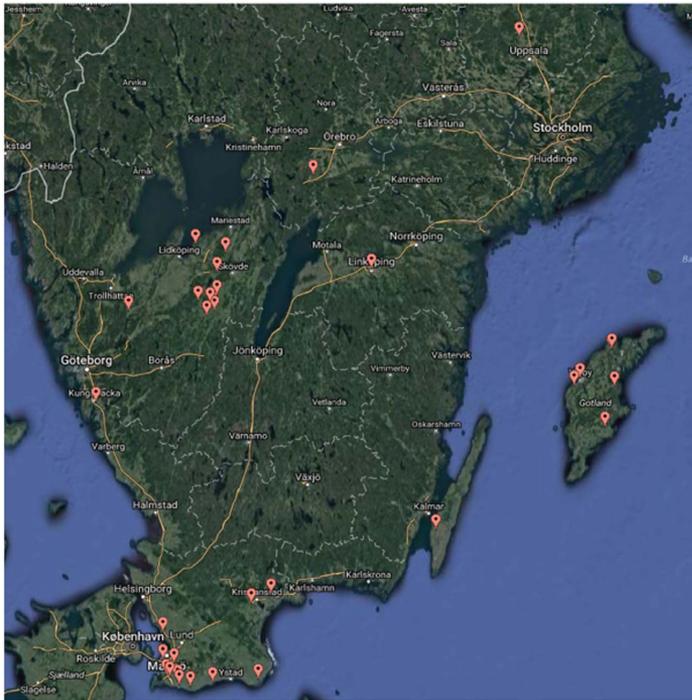


Fig. 2. Map of southern Sweden with sample sites marked. Map constructed through [Batchgeo.com](https://www.batchgeo.com/).

femoral length is as short in the LNII-EBA data as in the PWC-BAC, while there seem to be a peak in the LNI. The LNII-EBA female data also demonstrates the widest range, indicating a larger variation in stature between females associated with the LNII-EBA than with other Mesolithic-Neolithic cultures. Male femoral length in the TRB-PWC is equal to that of LNI females, strengthening the assumption of a significant increase in stature in the later part of the Neolithic for both sexes.

To evaluate if the increase in stature between the Mesolithic-PWC and BAC-EBA is statistically different, a non-parametric test was applied. In parametric statistical testing sample means are evaluated. Since the data from Neolithic Sweden is limited for some groups and subgroups, parametric statistical testing was considered too sensitive to outliers. In non-parametric tests median values for each group are used instead of mean values and this method was therefore considered more appropriate, considering the small sample sizes. A Kruskal-Wallis rank sum test was conducted to test the null-hypothesis that all populations exhibit equal stature. The significance level was put at 95% ( $p \leq 0.05$ ). The Kruskal-Wallis test showed that there is a highly significant difference ( $p \leq 0.001$ ) in stature between populations during the south Swedish late Mesolithic and Neolithic for both sexes (Table 4). The null-hypothesis could therefore be rejected.

#### 4. Discussion

This study presents evidence that there are statistically significant differences in stature between cultures in the south Swedish late Mesolithic-Early Bronze Age (EBA) for both sexes. There are some limitations in this analysis. Firstly, sample sizes in some of the groups and subgroups are not particularly large and are quite unevenly

distributed. To try to avoid as much bias as possible in statistical testing a non-parametric test (Kruskal-Wallis) was applied. Secondly, due to taphonomic reasons stature was estimated through maximum femoral lengths. The relationship between long bone length and living stature is known to differ between populations (Boldsen, 1984; Hens et al., 2000; Ously, 2012). Considering the temporal differences it could therefore not be completely ruled out that the populations under study do differ in this relationship, thus affecting the outcome. Further, a large proportion of the skeletons have not been fit for traditional sex estimation, partly due to fragmentation and misplacements in museum storages, but mostly due to a majority of the material deriving from collective graves with commingled remains that cannot be linked to individuals. Sex was therefore assessed through statistical methods based on sexual dimorphism. This approach could involve some misclassifications, but was considered less prone to bias than comparisons to modern data. Lastly, the data is only based on skeletal material inside present Swedish borders that did not exist during the Neolithic. Cultural expressions in much of present Denmark are equal to those of southern Sweden during this period, but skeletal data has only been included for comparisons. However, this study is the most comprehensive on south Scandinavian Neolithic stature so far. A majority of the individuals from the Late Neolithic and Early Bronze Age have been  $^{14}\text{C}$ -dated and not only through burial practice. This is considered crucial considering a widespread re-use of Late Neolithic gallery graves during the Early Bronze Age in southernmost Sweden.

The World Health Organization (WHO) uses human stature and other anthropometric values to evaluate physical status (World Health Organization, 1995). Stature is dependent on both genetic factors [~80%] and environmental factors [~20%], such as disease history

**Table 1**  
The total sample with the number of analysed individuals.

Chronology	Locality	# Individuals (both sexes)	Reference	
Ertebølle	Skateholm I	24	Persson and Persson (1988)	
	Skateholm II	17		
TRB	Rössberga	1	Ahlström, unpublished data	
	Fräsegården	14		
	Landbogården	2		
	Slutarp	21		
	Karleby	2		
	Resmo	7		
	Carlsbögen	4		
				Strömberg and Lepiksaar (1971)
PWC	Wetterlinggården	3	Tornberg, this study	
	Lockegården	6	Tornberg, this study	
	Ajvide	9	Persson and Persson (1997)	
	Fridtorp	10	Englund (1982)	
	Hall, Västerbys	2	Janzon and Gejvall (1974)	
BAC	Hemmor, När	2	Dahr, unpublished notes Tornberg, this study	
	Ire	7		
	Visby	12		
	Västerbjärs	13		
	Viby 26	1		
	Vellinge kv. Skolan	1		
	Lilla Beddinge	4		
				Tornberg, this study; Jantsch and Ranåker (2001)
				Jantsch and Ranåker (2001)
				Magnell (2007)
LNI	Kiaby 80:1	2	Tornberg, this study	
	Snorthög	5		
	Kjyhjbersbacken	2		
	Abbekås	2		
	Vellinge 27	1		
LN II-EBA	Abbekås	1		
	Backa	2		
	Dragby	3		
	Fredriksberg	2		
	Hammarlöv 6	1		
	Medelplana	1		
	Möllebacken	1		
	Rörbäck 10	1		
	Timmersdala	1		
	Vellinge 27	1		
	Ångamöllan	4		
	Ahlbäckbacken	2		
	Bonhöj	1		
Kjyhjbersbacken	1			
Torbjörntorp	2			

and available nutrition (Carmichael and McGue, 1995; Carson, 2012; Carson, 2010; Silventoinen et al., 2000). Malnutrition and illness in childhood can cause stunting during growth, even after a short period of bad conditions. If the bad conditions remain this growth retardation is demonstrated through shorter adult stature (Steckel, 2012). If mean stature is analysed in a population, genetic variation seems to be generally neutralised and changes in stature could be regarded as reflections of wealth and nutritional status (Steckel, 1995). Gunnell et al. (2001) and Kemkes-Grotenthaler (2005) found relationships between high stature and an increase in longevity in archaeological samples. Current Swedish mean stature is 179.4 cm for males and 165.7 cm for females. These statures are among the highest in the world and have been increasing rapidly from the mid-19th Century until present times (Statistics Sweden, 2013). This phenomenon is referred to as secular trend (Cole, 2000; Cole, 2003; Stinson, 2012; Bogin, 2013). This corresponds to the increase in wealth and health care system, changing Sweden from a poor agricultural society to a rich welfare state. Even though it is to be considered broadly accepted that good nutrition and good overall health are strong contributors to high stature; migration

could also have an effect. Societies that are influenced by a high level of exogamy also tend to have higher mean stature among the population, due to a higher diversity in the gene bank (heterozygosity) (Stinson, 2012, p. 601). However, the contribution of an increased gene-flow to higher stature is considered low (Stinson, 2012, p. 601). Steckel (2012) demonstrates that migration might even stunt growth, depending on the migrators being unaccustomed to the new microbial flora, causing both higher morbidity rates and an increased mortality among the newcomers for a few years.

Male mean femoral length increased from 43.02 cm in the Ertebølle period to 47.11 cm in the Early Late Neolithic (LNI). This corresponds to living stature of approximately 162.5 and 173.5 cm respectively. There is no visible difference in maximum femoral lengths between males of the TRB (43.89 cm) and the Pitted Ware Culture (PWC) (43.77 cm). There is however a small increase in male stature associated with the Neolithic transition (c. 2.5 cm living stature). This indicates that the only significant increase is associated with the Swedish-Norwegian Battle Axe Culture (BAC), where mean femoral length reaches 46.84 cm. This could be translated to an increase of c. 8 cm in living stature from the TRB/PWC to the BAC. This is lower than the secular trend visible in Sweden during the 1900s, where mean male stature at age 14 increased with 20 cm in a hundred years (Stinson, 2012), but still clearly different than in previous and partly contemporary periods. Stature then seems to have remained relatively constant from the Battle Axe Culture until the Early Bronze Age. Female stature also increases during the Neolithic. Contrary to male stature, female stature increases more evenly throughout the Neolithic, but tend to have a decrease in the later part of the Late Neolithic and Early Bronze Age. There is no visible stature increase for females associated to the transition to agriculture. Bennike (1985) also concludes that there was an increase in stature in Denmark from the Mesolithic (161.5/154 cm) to the Late Neolithic (176/163 cm) for males and females. However, the Single Grave Culture (Corded Ware Culture) is only represented by three individuals, with statures of 172 and 161 cm for males and females respectively. There is also a lack of  $^{14}\text{C}$ -dates that could give more detailed information about Late Neolithic-Early Bronze Age stature. Gerhards reports an increase in Latvian stature from 167/158 cm in the Middle Neolithic to 174/159 cm in the Late Neolithic-Early Bronze Age for males and females (Gerhards, 2005, 2006). These statures are lower than the Danish for both sexes. It should be noted that the Late Neolithic data from Latvia consists of individuals associated with the Corded Ware complex and falls within the Middle Neolithic periods in Denmark and Sweden. In opposition to the data from Sweden and Denmark, Gerhards (2005) reports a decrease of 10 cm in male living statures following the transition to agriculture c. 6500–6400 BP, which indicates that this change in subsistence meant increased stress for the people in present day Latvia, not present in southern Scandinavia. This might reflect differences in the way and pace agriculture was adopted as well as less favorable soils. Stature for both Denmark and Latvia is calculated using the Trotter and Gleser (1952) model. The south Swedish data corresponds quite well to both the Danish and the Latvian reports for Neolithic and Early Bronze Age data, although Danish data is a little higher both in the Middle Neolithic and the Late Neolithic sample. Since re-burials in megaliths are commonly practiced, it could however not be definitely precluded that the Danish data does not include Bronze Age or Iron Age individuals. If using the Trotter and Gleser (1952) model for assessing living stature, the male data from southern Sweden equals 167.35 cm in the TRB and 174.8 cm in the LNI. The south Swedish living stature in the BAC measures 174.2 cm and is consistent with those reported by Gerhards for Latvia. The Swedish female data spans from living statures of 152.8 cm in the Ertebølle to 162 cm in the LNI. The females associated with the BAC had a mean living stature of 158.8 cm. The Swedish TRB females seem to have been taller (152.9 cm) than the ones from Denmark, but clearly shorter than the Middle Neolithic females in Latvia. Late Neolithic female stature however seem to have been similar in

Table 2

Mean maximum femoral lengths for males and females in the complete sample ( $n = 203$ ). Values are divided in cultures and site names, and given in cm with standard deviations.

Male					Female				
	Locality	Mean	SD	No.	Locality	Mean	SD	No.	
Ertebölle	Skateholm I	43.14	2.88	10	Skateholm I	39.72	1.99	14	
	Skateholm II	42.86	2.18	8	Skateholm II	40.31	1.9	9	
Tot. Ertebölle		43.02	2.52	18		39.95	1.93	23	
TRB	Rössberga	43.9	0	1	Karleby	39.65	2.76	2	
	Frälsegården	42.97	1.10	3	Frälsegården	39.41	1.45	11	
	Slutarp	43.13	2.47	7	Slutarp	40.62	2.31	14	
	Wetterlinggården	45.57	0.85	3	Landbogården	37.7	2.12	2	
	Lockegården	45.14	1.89	5	Lockegården	43.3	0	1	
	Resmo	42.53	1.99	3	Resmo	40.3	1.92	4	
	Carlshögen	44.2	1.04	3	Carlshögen	38.6	0	1	
	Tot. TRB		43.89	1.98	25		39.98	2.07	35
PWC	Ajvide	40.82	1.89	5	Ajvide	39.85	0.82	4	
	Fridtorp	42.75	1.10	4	Fridtorp	42.97	2.09	6	
	Hall, Västerbys	43.2	0	1	Hall, Västerbys	41.3	0	1	
	Hemmor, När	43.1	0	1	Hemmor, När	40.4	0	1	
	Ire	43.58	2.44	5	Ire	41.1	1.98	2	
	Visby	44.99	1.23	10	Visby	40.55	2.05	2	
Tot. PWC	Västerbjärs	45.22	1.15	6	Västerbjärs	41.39	1.03	7	
		43.77	2.11	32		41.39	1.72	23	
BAC	Viby 26	47.6	0	1	Vellinge kv. Skolan	41.9	0	1	
	Lilla Beddinge	45.98	0.69	4	Dösemarken	40	0	1	
	Bergsvägen	48.8	0	1	Bergsvägen	45.3	0	1	
Tot. BAC	Gustav Adolf	47.6	0	1	Fredriksberg	42.4	0	1	
		46.84	1.25	7		42.4	2.19	4	
LN I	Kiaby 80:1	43.7	0	1	Kiaby 80:1	43.6	0	1	
	Snorthög	46.83	0.51	3	Snorthög	43.35	1.63	2	
	Kjyhjbersbacken	48.9	2.97	2	Vellinge 27	44.5	0	1	
	Abbekås	48.0	0.99	2					
Tot. LN I		47.11	2.14	8		43.7	1.09	4	
		45.2	0	1	Ahlbäckbacken	40.4	1.41	2	
LN II-EBA	Backa	46.85	1.06	2	Bonhöj	41.6	0	1	
	Dragby	47.9	0	1	Dragby	44.2	1.84	2	
	Fredriksberg	46.7	3.11	2	Kjyhjbersbacken	45.6	0	1	
	Hammarlöv 6	45.7	0	1	Torbjörntorp	40.9	4.81	2	
	Mesdelplana	45.5	0	1	Ångamöllan	40.5	0	1	
	Möllebacken	44.7	0	1					
	Rörbäck 10	47.7	0	1					
	Timmersdala	50	0	1					
	Vellinge 27	48.3	0	1					
	Ångamöllan	46.9	0.79	3					
	Tot. LN II-EBA		46.99	1.46	15		42.08	2.76	9

Table 3

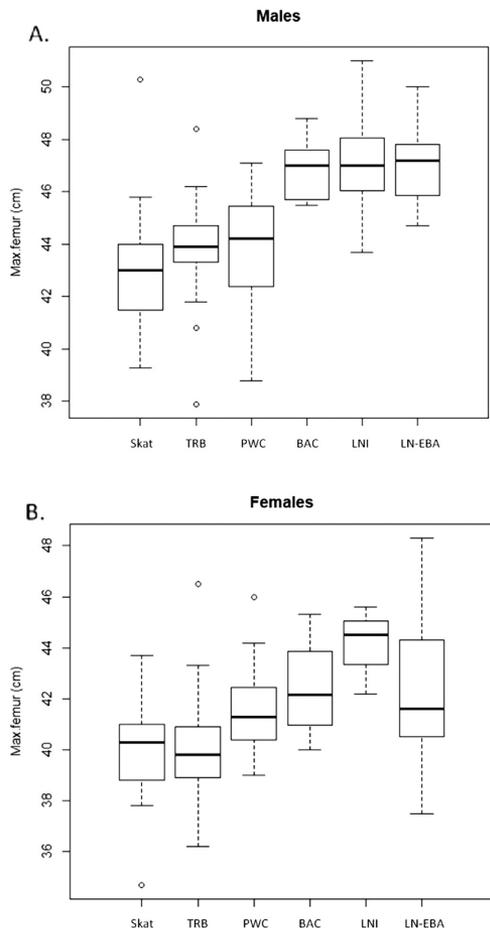
Mean and median maximum femoral lengths as well as calculated living stature of the sample ( $n = 203$ ). Standard deviations for mean maximum femoral length are available in Table 2.

Chronology/ Culture	#	Mean		Median		Calculated		
		Male	Female	Male	Female	Male	Female	
Ertebölle	18	23	43.02	39.95	43	40.3	162.4	154.1
TRB	25	35	43.89	39.98	43.9	39.8	164.8	154.2
PWC	32	23	43.77	41.39	44.2	41.3	164.5	158.0
BAC	7	4	46.84	42.4	47.0	42.15	172.8	160.8
LN I	8	4	47.11	43.7	47.0	44.5	173.5	164.3
LNII-EBA	15	9	46.99	42.08	47.2	41.6	173.2	159.9

Sweden and Denmark. The Swedish data from the BAC coincides with the Late Neolithic data from Latvia. It is clear that stature in southern Scandinavia was higher than in continental Europe during the Late Neolithic. Bruchhaus (2001) reports data supporting an increase in living stature from the Early Neolithic ( $\sim M = 166$ ,  $F = 157$  cm) to the Late Neolithic ( $\sim M = 170$ ,  $F = 160$  cm). Wittwer-Backofen and Tomo (2008) on the other hand report a decline in stature from the Early to Late Neolithic reaching as low as 163.6 and 157.1 cm for males and females respectively. Either there were other genetic influences or more

beneficial living conditions in northern Europe that allowed higher stature.

Largely, two things are known to affect stature: health and genetics. How can this be understood in relation to the archaeological context? It is clear that there is no difference in stature between the TRB and the PWC. The cultures partly overlap in chronology, which might reflect both similar genes and equally good living conditions, despite dependence on different subsistence. Neither is there any dramatic change in stature following the Neolithic transition. Ancient DNA data however suggests that there is a genetic distinction between individuals associated with the Pitted Ware Culture and those of the Funnelbeaker Culture (Malmström et al., 2009; Skoglund et al., 2012; Malmström et al., 2015) as well as between Mesolithic foragers and Neolithic farmers (Allentoft et al., 2015). Considering that these population display similar stature despite differences in genetic setup it might be reflective of a very low genetic contribution on stature, at least for these populations. Unfortunately, there is a lack of skeletal material from the Early Neolithic in southern Sweden. As a consequence there remains some uncertainty regarding the influence of the transition to agriculture on stature. Even though there is archaeological evidence of the Neolithic transition around 4000 BCE, this event is not reflecting in the human skeletal data in southern Sweden. Data does not support an increase or a decline in stature, as is present in other parts of the world following the transition to agriculture. This trend is consistent with



**Fig. 3.** Boxplot of maximum femoral length for A: males and B: females. Outliers are marked with circles. Ska = Skateholm (Late Mesolithic); TRB = Funnelbeaker Culture (Middle Neolithic A) PWC = Pitted Ware Culture (Middle Neolithic A-B foragers); BAC = Battle Axe Culture (Middle Neolithic B); LNI = Late Neolithic I; LNII-EBA = Late Neolithic II-Early Bronze Age. It is evident that there is an increase in male statures in association to the Battle Axe Culture that then remains more or less static throughout the Late Neolithic and Early Bronze Age. Female stature is increasing gradually throughout the Neolithic but decreases somewhat in the latest part.

**Table 4**  
The results of a Kruskal-Wallis rank sum test (maximum femur – chronology). The test shows that there is a statistical difference ( $p < 0.05$ ) in maximum femoral length between archaeological period for both sexes.

	Males	Females
Chi-squared	44.8937	21.3663
p-value	1.525e-08	0.0006906

other bioarchaeological parameters, such as dental caries, where caries frequency of only c. 3% is supported in the Middle Neolithic record (Ahlström, 2003). Data from southernmost Sweden however supports a

moderate increase in caries frequency (5.2%) in the Late Neolithic II- Early Bronze Age (Tornberg, 2017, accepted manuscript). The question is if it is adequate to speak of a consolidated Neolithic society already in the TRB.

Male stature seems to have increased in an event-like manner between the TRB/PWC and the BAC, with stature more or less consistent from the BAC through the Late Neolithic and Early Bronze Age. The sample size is not particularly big, but it is evident that there is a large difference in male stature following the BAC. Females tend to have had a more linear increase in stature throughout the Neolithic. This might depend on genetic factors. Males are thought to be more susceptible to environmental stress than females. This means males are at larger risk for stunting growth during bad times, as well as increased growth during good conditions, than females (Vercellotti et al., 2011; Stinson, 2012; Gibbon and Buzon, 2014). Wells (2012) also demonstrates that males have a higher trade off investment in lean weight (body weight - body fat weight) and females in body fat, in expense of the other. This means that males invest in higher stature during good conditions while females invest in higher levels of body fat. This is probably linked to the reproduction. However, differences in growth between males and females could also be expressions of cultural behavior, including differences in nutrition and care in societies where one sex is preferable over the other. The female LNII-EBA data indicates a decline in stature but also demonstrate the widest range. Bronze Age society is commonly associated with an increase in social inequality, closely connected to the development and distribution of metals (Vandkilde, 1996; Kristiansen, 1999; Earle, 2002; Kristiansen and Earle, 2015). Most modern data concludes that there is a difference in growth related to socioeconomic status both in affluent and poor countries (Stinson, 2012). It is possible that the decline in female stature is related to the incline in social inequality. Social inequality in Bronze Age burial contexts is primarily discussed from burial form and presence of high-quality bronzes. Håkansson (1985) interpreted the central grave in burial mounds as being the most prominent followed by other mound burials, flat earth burials and lastly re-burials in Late Neolithic gallery graves. Holst et al. (2013) argue that no > 20% of the Danish BA population was buried in mounds, and that 80% of the population therefore was missing from archaeological analyses. Bergerbrant et al. (2017) and Tornberg (2017) however found that the majority of burials in gallery graves in southernmost Sweden were in fact Bronze Age reburials, which was interpreted as being those of ‘commoners’. Tornberg (2017) also found differences in caries rates between burial types, possibly related to differences in diet. Only one of the female individuals (Bonhöög) dated to the Late Neolithic-Early Bronze Age is associated with a grave that fits the criteria of being high status. It is therefore possible that the decrease in stature among females in the latest period is due to the fact that the majority of the sample comprises individuals from a lower social status with possible differences in dietary habits and perhaps inferior health.

The understanding of the shift from the TRB to the BAC is still a scholarly debate. It is clear that the cultural expressions in the BAC is different from the TRB, but if this difference is due to local adaptation (Malmer, 1962; Malmer et al., 1986; Damm, 1991; Fokkens, 1998) or through migration (Kristiansen, 1989) is not yet concluded. Haak et al. (2015) recently published a study where results pointed to the Indo-European language being introduced through migrations from the area around Georgia during the 3rd millennium BC. The culture group responsible for this would then be the agro-pastoralists of the Yamnaya culture. Genetic studies of several prehistoric individuals indicate a significant Yamnaya influx at the time of European Corded Ware/Battle Axe Culture, around 2800 BCE, suggesting migrations from the east (Allentoft et al., 2015; Haak et al., 2015). The herders of the Yamnaya are shown to have high stature (Mathieson et al., 2015). It is possible that an influx of genetically influenced higher statures could be one answer to why there is an increase in stature in the later part of the Middle Neolithic. It is of importance to recognize that the data

supporting migrations associated to the Battle Axe Culture does not support a complete repopulation, but an admixture with populations already present in the area. Stature data from Central Europe show male statures below 170 cm (Wittwer-Backofen and Tomo, 2008), considerably lower than in south Scandinavia. Since the Yamnayan genetic signal is higher in the Central European Corded Ware Culture than in the Scandinavian (Allentoft et al., 2015), this cannot be the only explanation for high stature. Further, migration and an increased genetic diversity are generally considered to have only a minor influence on stature (Steckel, 1995; Stinson, 2012). Bogin (1999) argues that stature is more dependent on environmental factors (health, disease, social setting etc.) than on genetic ones, and as a consequence the answer to the increase in stature in the BAC is probably more complex than only due to genetic influx. Very high stature is evident in the wealthiest countries in the world in present day, increasing as nutrition standards and health care improves (Roberts and Manchester, 2005). Although it is possible that genetic influx might have been contributing to increased statures during the BAC, I argue that the primary contributing factor is that of increased access to nutrition provided by a pastoral subsistence that is often associated with the BAC, and probably influenced by contacts with people from the eastern steppes.

There are no clear traces of settlements during the first part of the Battle Axe Culture, indicating a mobile, pastoral lifestyle. Permanent settlements does not appear until the shift to the Late Neolithic, around 2300 BCE, where also a more open landscape is evident due to increased need of grazing areas (Andersson, 2003). Brink (2013) reports of early hamlets in the late BAC-LNI in southernmost Sweden and suggests that there might be a manifestation of some sort of farming cooperation, perhaps in relation to herding. The early villages also correlate with an intensified and more stable agro-pastoral economy during this time (Prescott, 2009). A pastoral subsistence is linked to a higher reliance on secondary products, such as milk. Milk consumption is proved as highly significant contributor to higher BMI among children in modern African pastoralists (Iannotti and Lesorogol, 2014) as well as higher stature among children and adolescents in modern Sweden (Almon et al., 2011). Lactose found in fresh milk also have qualities that makes it act like a vitamin D which helps the small intestine to resorb calcium (Durham, 1991), beneficial for health. Allentoft et al. (2015) found a higher level of lactase persistence (the genetic ability to digest milk in adulthood) in Corded Ware individuals than in previous European populations, indicating an increased reliance on dairy products as nutrition. This is also supported by zooarchaeological assemblages, at least from the later part of the Bronze Age (Vretemark et al., 2010). It is possible that an increased reliance on dairy products in relation to higher degrees of lactase persistence is partly related to this increase, and that an intensified agricultural practice with higher outcome has provided a well-nourished society with high stature. Unfortunately little work has previously been done on Late Neolithic-Early Bronze Age health in southern Sweden. However, analyses of paleopathology in the LN-EBA population of Abbekås, southernmost Sweden, show that *cribra orbitalia* was present in only one out of 18 individuals and enamel hypoplasia only in two, all adults (Tornberg, 2013). The situation of south-central Sweden is similar, where *cribra orbitalia* was non-existent and enamel hypoplasia, mostly affecting the canines, present in eight out of 28 individuals buried in the gallery grave Falköping stad 5 (Blank et al., manuscript). Paleodemographic modeling also point to low child mortality with a large part of the population surviving into their seventh and eight decade of life (Tornberg, manuscript).

An intensified focus on secondary products, such as milk/dairy, which has a high nutrient content, would thus be beneficial for health, and thus also stature, during the BAC-Late Neolithic. The shift towards a higher reliance on secondary products (milk, wool, traction, manure) is discussed as *The Secondary Products Revolution* by Andrew Sherratt (1981). This change in agricultural practice would provide an accumulated wealth and lead to population increase, which are considered

triggers for the social stratification and complexity during the Bronze Age (Earle, 1989; Sherratt, 1997). The increase, and maintenance of high stature during the late part of the Neolithic and Early Bronze Age in south Sweden coincide with a period of change; the archaeological and genetic record provide evidence for mobility, a more stable agro-pastoral economy, an increased reliance on secondary products together with an increased ability to digest milk, formations of hamlets and the development of a Bronze Age Society.

## 5. Conclusion

This article provides evidence of statistically significant differences in femoral length associated to chronology for both sexes. The data in this study is the most comprehensive on Neolithic stature in southern Scandinavia so far. The stature data from other parts of northern Europe is confirmed and strengthened, but I also demonstrate a more complex picture than was earlier documented. There is only a slight increase in male stature following the Neolithic transition and female stature is completely unaffected. This might suggest that the transition to agriculture at c. 4000 BCE did not affect health in a negative, but neither a positive way. There is a clear increase in male stature between the Funnelbeaker/Pitted Ware Cultures and the Battle Axe Culture. Male stature then remain more or less static throughout the Late Neolithic in to the Early Bronze Age. Female stature has a more linear increase throughout the whole Neolithic, although with a decline during the Early Bronze Age. The difference in growth patterns between males and females is interpreted as being caused primarily by biological factors, where males tend to be more susceptible to environmental changes affecting growth. It is however possible that the decline in female stature is related to an increase in social stratification associated to the Bronze Age. The high stature in the BAC-Early Bronze Age is probably due to a complex series of matters, dependent on genetic influx, population increase and good nutrition and health, possibly linked to an intensification and consolidation of the agro-pastoral economy. This is also visible in the material culture where village-like settlements starts to appear around 2000 BCE. On this background, it is possible that it is not adequate to speak of a fully established Neolithic society until the late Battle Axe Culture. These events eventually lead to economic surplus and the social formations of the Bronze Age.

This study includes data deriving from Late Neolithic skeletons that have previously been unstudied. Through <sup>14</sup>C-dating of the majority of the Late Neolithic-Early Bronze Age skeletal remains a more in-depth approach to changes in stature has been possible. The article provides important bioarchaeological results for the understanding of two central events – the transition to agriculture and the formation of Bronze Age society.

## Acknowledgements

This work was generously supported by the Ebbe Kock Foundation (EK2012-0058 and EK2015-0038) and Berit Wallenberg Foundation (BWS 2011.0074) with costs for running radiocarbon dates. Thanks to the project “The Rise – Travels, transmissions & transformations” for providing me with additional ones. I would like to send thanks to Lena Strid for useful language corrections. Thanks also to Professor Torbjörn Ahlström, for feedback on this article, and especially for generously providing me with Middle Neolithic data.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jasrep.2017.10.031>.

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# Paper III





## Original Study

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# New Perspectives on the Late Neolithic of South-Western Sweden. An Interdisciplinary Investigation of the Gallery Grave Falköping Stad 5

<https://doi.org/10.1515/opar-2018-0001>

Received May 14, 2017; accepted January 1, 2018

**Abstract:** This article presents the results of an interdisciplinary study combining archaeology, osteology, and stable isotope analyses. The geological conditions and richness of megalithic graves in Falbygden is suitable for studies of Neolithic human remains. Nevertheless, the Late Neolithic period (2350–1700 BC) is poorly investigated. This paper explores new knowledge of the Late Neolithic megalithic population in Falbygden. In-depth osteological and archaeological studies focusing on a single gallery grave (Falköping stad 5) were conducted. Radiocarbon dating and carbon, nitrogen, and strontium isotope analyses of teeth from twenty-one individuals revealed the time of the grave's use, as well as the subsistence and mobility practices of the buried individuals. The grave was already in use during the first part of the Late Neolithic and used into the second part of the period by individuals of different origin. Furthermore, the results indicated changing population dynamics in the Late Neolithic Falbygden, with increased human mobility, variability in subsistence strategies, and growing population density.

**Keywords:** subsistence, mobility, health, Scandinavian Late Neolithic, south-western Sweden, isotopes, osteology

## 1 Introduction

This paper discusses a Late Neolithic burial community, focusing on all identified individuals from a gallery grave in south-western Sweden. It uses an interdisciplinary approach that combines archaeology, osteology and isotope analysis on human remains from a single grave, which in turn allows in-depth studies of the variation in the megalithic population on a local and regional scale.

Osteological and isotope analyses are continuously developing and have become well established in archeological research (Eriksson, 2004; Eriksson & Lidén, 2013; Eriksson et al., 2008; Fernandes et al., 2015; Fomander et al., 2008; Knipper et al., 2015; Montgomery & Evans 2006; Bergerbrant et al., 2013; Sjögren et al., 2016). Interdisciplinary studies combining archaeology, osteology, and biochemical analyses are not as common, but are currently at rapid development (Carlie et al., 2014; Knipper et al., 2017; Pearson & Meskell, 2015; Scorrano et al., 2014; Wilhelmson, 2017a). These interdisciplinary studies are often based on large numbers of samples from extensive study areas. However, the sample size from each site is generally low, which could generate data biased by low variability within each site, thus providing overly generalized results.

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Falbygden, in the inland of south-western Sweden, is an important area for research on Neolithic megalithic graves in Scandinavia (Ahlström, 2009; Scarre, 2010; Shanks & Tilley, 1982; Sjögren, 2003; Tilley, 1994). It has one of Northern Europe's largest concentrations of passage graves and a substantial number of gallery graves. The numerous megalithic graves and various find concentrations indicate its status as an important area during the Middle and Late Neolithic (3350–2350/2350–1700 BC) (Bägerfeldt, 2009; Sjögren, 2003; Weiler, 1994). Systematic studies of the associated burials have been ongoing since 1860 with a particular focus on the passage graves and the Middle Neolithic period (Anderbjörk, 1932; Hildebrand, 1864; Montelius, 1873; Persson & Sjögren, 2001; Retzius, 1899; Sahlström, 1932; Shanks & Tilley, 1982; Sjögren, 2003; 2008), while only a few studies have dealt with the gallery graves and the Late Neolithic in the area (Algotsson, 1996; Anderbjörk, 1932; Blank, 2016, 2017; Stensköld, 2004; Weiler, 1994).

The Scandinavian Late Neolithic (2350–1700 BC) has been described as a period of increased social complexity, growing population density, and stronger reliance on agriculture (Apel, 2001; Artursson, 2009; Lekberg, 2002; Vandkilde, 1996; Kristiansen & Larsen, 2005). Most of the research is based on artefact studies; however, it may be useful to consider whether there is any bioarchaeological evidence of population increase, higher mobility, changes in subsistence, or increased nutritional access in the Late Neolithic megalithic population compared to the megalithic Middle Neolithic population in Falbygden.

The calcareous soils of Falbygden have promoted excellent bone preservation, allowing osteological studies, radiocarbon dating, and stable isotope analyses of skeletal remains. The geology of the region is dominated by Cambrosilurian sedimentary rock (550–400 Ma), which differs from the Precambrian crystalline bedrock (1.86–0.9 Ga) in the surrounding areas (Figure 1), and thus increases the likelihood of detecting mobility through strontium isotope analysis. The human and animal remains from Middle Neolithic passage graves and settlements have been subjected to thorough osteological investigations (Ahlström, 2001, 2009). A number of isotope studies measuring  $^{14}\text{C}$ ,  $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$  values and  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios in human and animal remains from this area have been conducted (Hinders, 2011; Lidén, 1995; Persson & Sjögren, 1995; Sjögren, 2011, 2017; Sjögren & Price, 2006, 2013a, 2013b; Sjögren *et al.*, 2009). These publications all discuss the Middle Neolithic period, while isotopic studies of the Late Neolithic are still few (Blank, *in press*; Blank, Knipper, *in press*).

This study presents new knowledge about the Late Neolithic population buried in megalithic graves by focusing on the bone material found in the gallery grave at Falköping stad 5 in Falbygden. It addresses this subject through analyses of the time of use of the gallery grave, as well as the health, paleodemography, diet and subsistence, and mobility of the individuals buried there, and compares these results with previously published studies of the Late and Middle Neolithic in Falbygden, as well as from other south Scandinavian regions.

## 2 Background

### 2.1 Archaeological Background

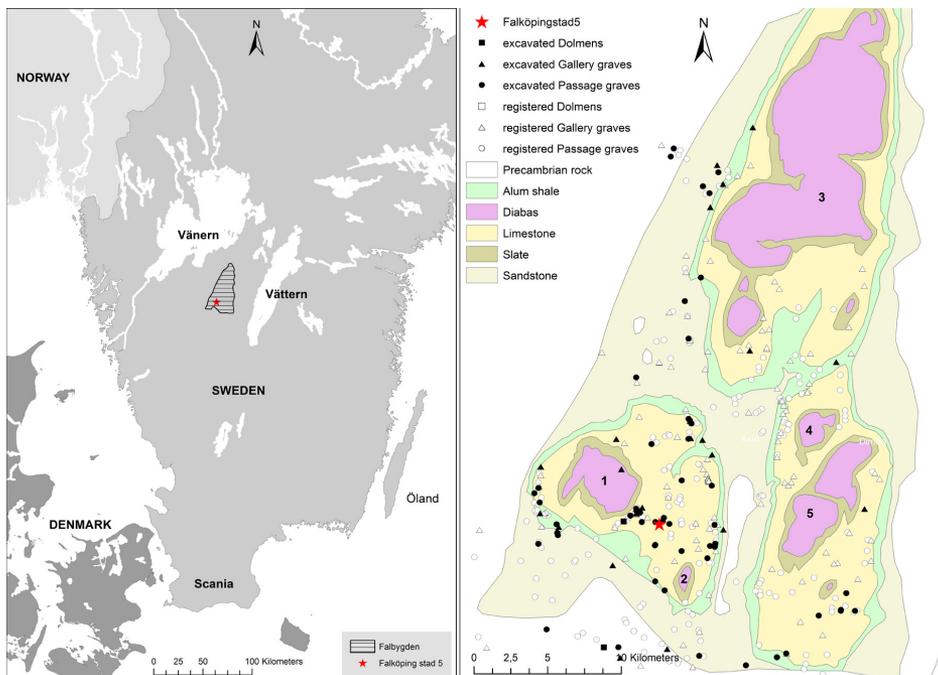
The Scandinavian Late Neolithic is a period defined by new types of materials, complex flint-working techniques, the appearance of gold and copper artefacts, and long distance trading networks (Apel, 2001; Ling *et al.*, 2014; Kristiansen & Larsen, 2005; Vandkilde, 1996). The first part (2350–1950 BC) of the Scandinavian Late Neolithic is contemporary with the later years of the Beaker phases in the British Isles and the Rhine delta and the Early Bronze Age in Central Europe, while the second part (1950–1700 BC) overlaps with the Wessex I phase in the British Isles, the barbed-wire Beaker phase in the Rhine delta, and the Únétice phase in central Europe (Vandkilde, 1996). Influences from these culture complexes are visible in the rather homogenous Scandinavian Late Neolithic material (Apel, 2001; Iversen, 2015; Vandkilde, 1996).

In Scandinavia, the period is also associated with the constructions of gallery graves. It is likely that only part of the population during the Late Neolithic were buried in gallery graves and that other burial practices were in use, although they are not common in the archaeological record. In some parts—for

example, in Scania—, inhumation burials in flat graves occur (Bergerbrant et al., 2017; Tornberg, 2017). In Falbygden, on the other hand, only gallery graves have been found to date.

In Sweden, gallery graves are concentrated in western Sweden and Småland, southern Sweden. The graves in western Sweden are generally larger than the ones found in Denmark, Scania in southernmost Sweden, and eastern Sweden (Iversen, 2015, p. 123f; Weiler, 1994, p. 56). The emergence of gallery graves has been explained by influences from Denmark, which in turn have been explained by a development of the Single grave culture stone cists in Jutland (Ebbesen, 2004, p. 23; Iversen, 2015, p. 124; Janson, 1938, p. 321). It has also been suggested that the larger graves are inspired by burials in northern France and central Germany, considering the apparent resemblances to *allées couvertes*/ *allées sépulcrales* and the concentration of gallery graves with portholes in western Sweden (Ebbesen, 2004, p. 62; Janson, 1938, p. 330ff). Anderbjörk (1932, p. 26ff) and Montelius (1905, p. 170ff), however, also underline the continuation of the megalithic tradition and the resemblances with the earlier passage graves in Falbygden.

Falbygden is a 50 × 30 km sedimentary rock area (Figure 1) where 255 passage graves, 125 gallery graves, 2 dolmens, and 115 megalithic graves of unknown types have been documented (Persson & Sjögren 2001, p. 6). Only a small number of the graves have been excavated, most only partially, and the methods vary according to the excavation standard of the time (Blank, 2016, p. 52; Weiler, 1994; Sjögren, 2003). One of these is the gallery grave Falköping stad 5, also known as Fredriksberg, located in the limestone area between the mountains Mösseberg and Ålleberg, in the south-western part of Falbygden (Figure 1). Falköping parish is the densest area of gallery graves in Sweden, with one grave per 0.5 km<sup>2</sup> (Weiler, 1994). In 1973, after being damaged by construction work, Falköping stad 5 was excavated and restored (Weiler, 1977).



**Figure 1.** The location of Falbygden and Falköping stad 5. 1: Mösseberg, 2: Ålleberg, 3: Billingen, 4: Varvsberget, 5: Gerumsberget.

The grave was placed on a small ridge and dug into flat ground. It was constructed of limestone slabs and consisted of a chamber and antechamber, 5.3×2 m large slightly trapezoid and orientated NNE-SSW (Figure 2). Roof slabs that had collapsed into the grave were found in the chamber. These slabs were covered by a stone packing mixed with soil. The floor consisted of flat limestone slabs. The chamber and antechamber were separated by two limestone slabs with a slit at the top. The antechamber was somewhat lower than the chamber (Weiler, 1977). The size, orientation, and construction details reflect the common characteristics of gallery graves in south-western Sweden (Weiler, 1994).



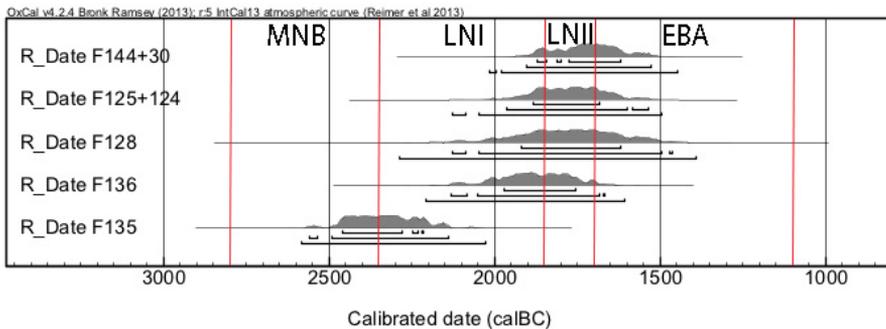
Figure 2. Photo and drawing of Falköping stad 5 during excavation. Photo by Ullberg, 1973, Falbygdens museum. Drawing based on Weiler (1977, p. 18).

During excavation the grave was divided in different sections and layers and the finds were documented in these units. The bone material lacking stratigraphic and spatial information derives from the top layer (Weiler, 1977, p. 12). Both the antechamber and the chamber contained artefacts as well as human and animal skeletal remains, although most of the material was found in the chamber. The majority of the bones derived from human burials, but remains from cattle, sheep/goat, pike, fox, rodent, and dove were also found (Weiler, 1977). Almost all of the artefacts were found in the bottom layers and consisted of remains from a decorated ceramic vessel, a flint dagger, seventeen flint flakes, six amber pendants, a slate whetter, a round and flat bone bead, two bone needles, a bone awl, and a bone artefact interpreted as a flute (SHM 32384). The skeletons were commingled and in a fragmentary state, suggesting they were moved to make room for new burials. Successive burials are supported by the presence of different and small bone elements which is consistent with recent research of the megalithic graves of Falbygden suggests (Ahlström, 2009; Sjögren, 2003). There were no signs of later activities in the grave (Weiler, 1977).

Compared to other excavated gallery graves in the surrounding area, Falköping stad 5 did not contain a lot of artefacts, even though it did not show any trace of looting or later reuse as many other megalithic graves in the area do (Weiler, 1977). It contained amber pendants, bone needles, and awls, which are common in both passage and gallery graves. The pottery found in Falköping stad 5 consisted of a rim sherd of a vessel with an estimated rim diameter of 10 to 15 cm. The rim is flared and the sherd is decorated by uneven rows of small pointed impressions. This type of ware and decoration is commonly found in Late Neolithic gallery graves in western Sweden and south Scandinavia, even though the sherd is relatively thin (5mm) (Anderbjörk, 1932, p. 38; Stilborg, 2002, p. 78). The shape of the sherd indicates an s-shaped vessel with a pronounced profile. The amber beads are not well preserved, but an oval pendant and two pendants of unknown shape with double holes can be identified. Amber pendants are common in megalithic graves both during the Middle and Late Neolithic. The flat and round bone bead is not a common find in the

gallery graves of western Sweden. However, this kind of artefact can have been easily missed due to its small size (6mm in diameter) and can only be expected to be preserved in certain environments. Bone implements are common both in passage and gallery graves, even though bone needles (dress needles) are mostly associated with the Late Neolithic. The bone needles in Falköping stad 5 are simple and lack ornamentation. However, one of the needles could be identified as type A:4 according to Hjærtner-Holdar's typology (1978, p. 236). A flint dagger of Lomborg type IIB had been placed in the chamber (Lomborg, 1973, p. 44). This type is not so common in the gallery graves in Falbygden, and is generally dated to the Late Neolithic I (Apel, 2001).

An osteological analysis was conducted by Iregren (1977), who estimated a minimum number of individuals (MNI) of thirty—ten children and twenty adults. The adult MNI was estimated by the presence of left distal humerus. Iregren (1977) reported ten males and six females based on characteristics of the pelvis. Five of the individuals were  $^{14}\text{C}$  dated when the gallery grave was excavated in 1973 (Weiler, 1977, p. 23). These analyses were performed by the Laboratory of Radioactive Dating in Stockholm with the conventional method (St-5149 to 5153 and 5157) (Weiler, 1977, p. 23). The dates imply that the grave was already in use during the Middle Neolithic B (2800–2350 BC) (Figure 3). Based on demographic calculations made by Jan Grandell (in Iregren, 1977, p. 62ff), Iregren suggests that the grave was in use for about one-hundred years and that it is most likely that the site was a family grave (Iregren, 1977, p. 51). As seen in Figure 3, the uncertainties of these dates are too significant to say anything more than that the grave was in use during the Late Neolithic.



**Figure 3.** Five previously radiocarbon dates on human bones from Falköpingstad 5. OxCal v.4.2.4 Bronk Ramsey (2013); r:5 IntCal13 atmospheric curve (Reimer et al. 2015). F144+30: St-5157, F125+124: St-5149, F128: St-5150, F136: St-5153, F135: St-5152. The red lines mark different periods: MNB: Middle Neolithic B, LNI: Late Neolithic I, LNII: Late Neolithic II and EBA: Early Bronze Age.

## 2.2 Isotope Analysis

Carbon ( $\delta^{13}\text{C}$ ) and nitrogen ( $\delta^{15}\text{N}$ ) isotope values in human bone collagen can be used to evaluate prehistoric food consumption (Sealy, 1986, 2001). For example,  $\delta^{13}\text{C}$  distinguishes terrestrial or marine diets, as marine organisms exhibit higher  $\delta^{13}\text{C}$  values (Sealy, 1986). In the Atlantic/North Sea region, terrestrial mammals have  $\delta^{13}\text{C}$  end values of bone collagen ranging from -20‰ to -21‰, whereas the marine end value is about -12‰. Intermediate  $\delta^{13}\text{C}$  would thus reflect a combination of marine and terrestrial proteins. In the Baltic region, the terrestrial  $\delta^{13}\text{C}$  values are similar whereas the marine end values are -14‰ to -15‰ (Lidén & Nelson, 1994). Nitrogen, which is absorbed by humans through consumed proteins, is also useful when the diet of prehistoric humans is investigated. Delta $^{15}\text{N}$  values have generally been suggested to increase along the food chain by about 3 to 5‰ per trophic level (Hedges & Reynard, 2007). In a terrestrial food web, this standard model implies  $\delta^{15}\text{N}$  values of 3‰ in plants, 6‰ in herbivores, and 9‰ in carnivores. Thus, bone collagen in human consumers of terrestrial plants and animals should have  $\delta^{15}\text{N}$  values between 6 and

10‰. However, recent data implies higher enrichment rates and variation within and between species, and enrichment up to 6‰ has been suggested (O'Connell *et al.*, 2012). This range of values has been considered in several recent papers (see Hedges & Reynard, 2007; Sjögren & Price, 2013b; Wilhelmson, 2017b). Thus, the interpretation of the origin of the protein might differ depending on which fractionation level is considered. Consumers of fresh water and marine fish and other aquatic predators show  $\delta^{15}\text{N}$  values of up to 15 to 20‰ as aquatic food webs have generally longer food chains than land-based webs (Eriksson, 2013; Schoeninger *et al.*, 1983, p. 130). The Baltic Sea has varied substantially in salinity through history (Emeis *et al.*, 2003). Since different species need different salinity to thrive the variation in salinity is connected to a variation in occurring species and probably also number of levels in the food chain. This variation should be taken into consideration when interpreting  $\delta^{15}\text{N}$  values in comparison with other published data from eastern Sweden.  $\Delta^{15}\text{N}$  values can also be affected by breastfeeding and the consumption of juvenile herbivores as these are one trophic level above their mothers. Physiological stress, famine, climate, elevation, and the intake of manured crops are other factors which can elevate  $\delta^{15}\text{N}$  values in human bones (Eriksson, 2013, p. 130, 36; Fraser *et al.*, 2011; Hedges & Van Klinken, 2002).

Different bone tissues reflect different components of the diet. Bone collagen mainly reflects protein intake, while bone and enamel carbonate (apatite) mirrors overall dietary components (protein, carbohydrates, and fats) (Ambrose & Norr, 1993, p. 121–55). The difference between the  $\delta^{13}\text{C}$  in apatite and the  $\delta^{13}\text{C}$  in collagen (the collagen-apatite spacing) observed in carnivores is smaller than in herbivores, while collagen-apatite spacings of  $6.8 \pm 1.4\text{‰}$  for herbivores,  $5.2 \pm 0.8\text{‰}$  for omnivores, and  $4.3 \pm 1.0\text{‰}$  for carnivores have been suggested (Hedges & Van Klinken, 2002; Lee-Thorp *et al.*, 1989).

Strontium originates from weathering rock minerals and the element passes through soils and water into the biosphere, travelling through the food chain into the human skeleton with minimal isotope fractionation (Bentley, 2006). Hence, the  $^{87}\text{Sr}/^{86}\text{Sr}$  ratio is effective for identifying human and animal mobility. The bio-available strontium isotope signature largely reflects geology, as  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios in rocks and minerals depend on their original Rb/Sr ratio as well as their geological age ( $^{87}\text{Rb}$  radioactively decays to  $^{87}\text{Sr}$ ) (Faure, 1986). However, in regions with loess or glacial deposits, the isotope ratio of the bio-available strontium can be very different from the underlying geology. Furthermore, various minerals weather at different rates and have different strontium concentrations and isotope ratios. The isotope signal can also be affected by sea spray, heavy rain, and atmospheric dust (Bentley, 2006; Frei & Price, 2012; Montgomery, 2010).

Hence, the strontium isotope signals in humans mirror the bio-available signal where they have resided. This approach assumes that the water and food which humans consumed were procured locally (Montgomery, 2010, p. 325). In humans, plants are the main contributors to strontium uptake, while meat contributes less and the importance of drinking water has been debated (Bentley, 2006, p. 154; Frei & Frei, 2013, p. 158; Montgomery, 2010, p. 329). For mobility studies, a consideration of diet is relevant, as considerable portions of marine food can shift the isotopic signal towards the seawater ratio of 0.7092 (Bentley, 2006).

When sampling skeletal remains, tooth enamel is often preferred, as it is less susceptible to diagenesis and contamination (Bentley, 2006; Montgomery, 2010, p. 329). Bone undergoes continuous chemical and structural turnover during life, while enamel forms in infancy, childhood and youth (depending on the kind of tooth) and remains unchanged thereafter. The recognition of specific events of mobility based on enamel analyses is therefore restricted to the childhood and youth of the sampled individuals (Hillson, 1996). It can take several years before the enamel is completely crystallized (Hillson, 1996) and the measured ratio is a mean value of the isotope signals incorporated during this time. If a person moves to a new location with a different geology after the tooth enamel has formed, the strontium isotopic ratio from their enamel will differ from the bio-available strontium isotope signal from that location, and register as non-local. However, if the range of  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios in the different locations is the same, it is not possible to identify non-local individuals.

In Sweden, baseline ranges have been determined only in a few restricted areas, mostly in connection to specific archaeological sites (Arcini *et al.*, 2015; Blank & Knipper, *in press*; Eriksson *et al.*, 2016; Fornander *et al.*, 2015; Frei, 2009; Price, 2013; Sjögren *et al.*, 2009; Sjögren & Price, 2012; Sjögren & Price,

2006; Wilhelmson & Ahlström, 2015; Wilhelmson & Price 2017; Price et al., 2017). A preliminary overview of strontium isotope ratios in south-western Sweden has been published by Blank and Knipper (in press). However, the isotope signal of the bio-available strontium in Falbygden is relatively well known. In previous research, seventy-eight samples from domestic and wild animals and eighty-two humans from southwest Sweden, mainly from the area of Falbygden, were analysed (Sjögren et al., 2009; Sjögren & Price, 2012). These studies show a clear division of the Cambrosilurian area (Falbygden) and the surrounding Precambrian provinces (Figure 1). Based on previous and ongoing studies, the isotope signal of the bio-available strontium in Falbygden ranges from 0.713 to 0.716, with higher ratios ranging from 0.717 to 0.726 in the surrounding Precambrian areas (Sjögren et al., 2009; Sjögren & Price, 2012). These ranges can be confirmed in a thorough baseline study of inland western Sweden (Blank et al., in press).

### 3 Material and Methods

The Falköping stad 5 gallery grave was chosen for this study for several reasons: it is well documented and not disturbed by later activity, it contained a substantial number of well-preserved human remains suitable for osteological and isotope analyses, and the results from previous analyses needed reevaluation. The gallery grave contained burials from at least twenty-eight individuals, including nine children and nineteen adults (MNI). Iregren (1977) estimated MNI to be thirty, based on twenty distal adult humeri and ten juvenile mandibles. In the current osteological analysis by Tornberg, only fifteen adult distal humeri were detected. One humerus was sent in for radiocarbon dating in the 1970s, but the remaining absence of four humeri cannot be explained further. The high adult MNI calculated through the presence of left tali ( $n=19$ ) and calcanei ( $n=18$ ) is the same in both studies. In the present study, MNI is estimated through the presence of mandibles divided in six different age categories and through the number of left adult tali. When comparing current osteological analysis to Iregren's report, mandibles from F142, F85, F38, F123 and F122 are missing. However, three mandibles not present in Iregren's report, that could not be associated to any of the other mandibles, were documented in the current study (F 129 V:2, F 139 VII:2 and F 134). It is possible that differences in calculations of the MNI are partly due to further fragmentation caused by insufficient packaging in the museum storage, and partly to inter-observer error. It should be noted that these calculations are the minimum number of individuals buried in Falköping stad 5 and that it is possible that more individuals were actually buried. This approach to the number of buried individuals is however necessary since the grave contains no articulated individuals.

To evaluate the frequency of dental caries and dental calculus, a total number of 287 permanent, erupted teeth were analysed. Eighty-eight teeth were incisors and canines and 199 teeth were premolars and molars, from both the upper and lower dentition. Seven teeth, including five incisors, one canine, and one premolar, could not be observed for carious lesions due to fragmentation. Therefore, 280 teeth are included in this study, including eighty-two incisors and canines and 198 premolars and molars.

A maximum of separate individuals based on teeth were sampled for isotope analyses of both enamel and collagen. In this case, molars (mostly second molars, which are suitable for strontium isotope analysis) from the lower dentition were selected from twenty-one individuals (Table 1). The enamel was used for  $^{87}\text{Sr}/^{86}\text{Sr}$  and  $\delta^{13}\text{C}$  analysis, and the root of the tooth was used for  $^{14}\text{C}$ ,  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  analysis.

Sex has been assessed through morphological characters on the os ilium and os pubis when applicable. Since the skeletal remains cannot be deduced to articulated individuals, it has been necessary to use secondary morphological characteristics of the skull and mandible as indicators of sex in the tooth-sampling procedure for stable isotopes and dental calculus analyses.

Adult age has been assessed using degenerative features of the pubic and auricular facets, as well as transition analysis (TA) when possible (Boldsen et al., 2002). Transition analysis is based on Bayesian modelling where population demographic patterns are used as prior information. The TA was carried out using the ADBOU software (Boldsen et al., 2002, available at <http://math.mercyhurst.edu/~sousley/Software/>) with an archaeological population of unknown ancestry as a model. In the sampling procedure for stable isotopes, an approximate age based on dental wear (Brothwell, 1981) was assessed. Juveniles have been aged using traditional

osteological analysis of dental eruption and epiphyseal fusion. Demography has been analysed using a Siler-competing hazard model (Ahlström, 2015; Siler, 1979, 1983; Wood *et al.*, 2002). The model is based on three components of human mortality. The first (immature) component refers to the high but decreasing infant and early child mortality. The second (residual) component is a constant-age, non-specific mortality hazard (e.g. accidents, violence, etc.), and the third (senescent) component is related to the increased risk of dying with increased age. The Siler model has five parameters that models mortality:  $\alpha_1$ =immature mortality rate,  $\beta_1$ =the rate of immature mortality decline,  $\alpha_2$ =residual mortality,  $\alpha_3$ =the initial adult mortality rate, and  $\beta_3$ =the rate of adult mortality increase. The Siler analysis was carried out using the free statistical software Ri386 version 3.1.3. Adults that could not be aged more precisely aged ( $n=7$ ) were weighted and divided between age spans so that the analysed sample would include the complete MNI, as leaving these individuals out would have biased the sample towards higher child mortality in relation to the whole population.

**Table 1.** Individuals sampled for isotope analysis.

Ind. No.	Context	Sample
F83III:1	Layer 1, northern part of chamber	M2, mandibula, sin
F139II:2	Layer 2, northern part of chamber	M2, mandibula, dexter
F90	Upper part, northern part of chamber	dpm2, mandibula, dexter
F115VII:2	Layer 2, southern part of chamber	M2, mandibula, dexter
F132VI:3	Layer 3, southern part of chamber	M2, mandibula, sin
F117	Layer 4, northern part of chamber	M2, mandibula, dexter
F108IV:3	Layer 3, northern part of chamber	M2, mandibula, dexter
F98	Layer 2, northern part of chamber	dpm2, mandibula, dexter
F147VI:4	Layer 4, southern part of chamber	M2, mandibula, dexter
F123	Upper layer, unknown	M2, mandibula, dexter
F122	Layer 4, southern part of chamber	M2, mandibula, dexter
F119	Layer 3, northern part of chamber	dpm2, mandibula, dexter
F121	Layer 3, southern part of chamber	M2, mandibula, dexter
F134	Layer 3, southern part of chamber	M1, mandibula, sin
F69	Upper part, southern part of chamber	M2, mandibula, dexter
F124	Layer 3, northern part of chamber	M2, mandibula, dexter
F118	Layer 3, northern part of chamber	M1, mandibula, dexter
F88	Ante chamber	dpm2, mandibula, dexter
F129V2:2	Layer 2, under roof slab western part	M1, mandibula, dexter
F128	Layer 3, northern part of chamber	M3, mandibula, dexter
F120+132	Layer 3, southern part of chamber	M1, mandibula, dexter

Stature estimations were based on the maximum length of the femur (Martin 1) (Martin & Saller, 1957) and calculated using the Sjøvold (1990) model. Paleopathological features were studied macroscopically under a bright light and registered, together with a description, as present, absent, or non-observable. Dental caries was investigated macroscopically under a bright light, with a magnifying glass when necessary. Only real cavities were registered as dental caries, while discolorations or initial enamel demineralization was not considered as dental caries. Dental caries was registered as: 1=occlusal surface, 2= interproximal, 3=smooth surface, 4=cervical caries, 5=root caries, 6=large caries with unknown origin, 7=non-carious pulp exposure, 0=non detectable and 9=non observable. Dental calculus was scored 1–3 (slight, medium, severe), absent (0) and non-observable (9).

Dating and analyses of stable carbon and nitrogen in collagen were conducted at the <sup>14</sup>Chrono Centre in Belfast. Collagen was extracted through a modified Longin method (Longin, 1971), developed by Brown

et al. (1988). The samples were pretreated using a simple ABA treatment, followed by gelatinization and ultrafiltration with a Vivaspin filter cleaning method (Reimer et al., 2015). The  $^{14}\text{C}/^{12}\text{C}$  and  $^{13}\text{C}/^{12}\text{C}$  ratios were measured by accelerator mass spectrometry (AMS) on an NEC 0.5 MV compact accelerator. The sample  $^{14}\text{C}/^{12}\text{C}$  was background corrected and normalised to the HOXII standard (SRM 4990C). The radiocarbon ages were corrected for isotope fractionation using the AMS measured  $\delta^{13}\text{C}$ . A Thermo Flash 1112 elemental analyser coupled to a Thermo Delta V mass spectrometer (EA-IRMS) were used to measure  $\%C$ ,  $\%N$ ,  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  within the sample. Samples and standards were sealed into tin capsules and combusted in the elemental analyser, which yields  $\%C$  and  $\%N$ , and C:N ratios were calculated from these values. The EA was connected to the IRMS for the stable isotope analysis. Three blanks were measured at the start of the run followed by three standards of Nicotinamide for the  $\%C$  values. The samples were run in duplicate (Reimer et al., 2015).

For stable carbon isotope analyses of bioapatite, 800 to 850  $\mu\text{g}$  of enamel powder were balanced into borosilicate exainers, which were closed with silicone rubber septa. After flushing with helium, the samples were reacted with concentrated phosphoric acid for 2 h at  $70^\circ\text{C}$ . The isotope composition of the resulting  $\text{CO}_2$  was measured using a GasBench II coupled to an isotope ratio mass spectrometer (Thermo Finnigan MAT 253) at the Institute of Geosciences, Department of Applied and Analytical Palaeontology at the University of Mainz, Germany. The isotope data were calibrated against the internal IVA-Carrara marble standard with  $\delta^{13}\text{C} = 2.01\text{‰}$ , and the measurement quality checked against NBS 19. Average internal precision ( $1\sigma$ ) was better than 0.04 for  $\delta^{13}\text{C}$ .

Enamel sample preparation and strontium isotope analysis were carried out at the Curt Engelhorn Center for Archaeometry in Mannheim, Germany following Knipper et al. (2012). Enamel chips were cut from complete teeth using a diamond-coated dental cutting disc. Adhering dentin and all surfaces were thoroughly removed, and the chips ground in an agate mortar. Pretreatment of the powders included soaking in de-ionized water in an ultrasonic bath, followed by the same procedure with 0.1 M acetic acid buffered with Li-acetate (pH 4.5) and three rinses with de-ionized water. Samples were dried overnight and ashed. Strontium separation with Eichrom Sr-Spec resin was carried out in clean laboratory facilities. Strontium concentrations were determined using a Quadrupole-Inductively Coupled Plasma-Mass Spectrometry (Q-ICP-MS) and the  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios using a High Resolution Multi Collector-ICP-MS (Neptune). Raw data were corrected according to the exponential mass fractionation law to  $^{88}\text{Sr}/^{86}\text{Sr} = 8.375209$ , to correct for isotope fractionation during measurement.

The statistical analyses were performed using the software SPSS version 23. The data evaluation included descriptive statistics and significance tests. As a normal distribution cannot be ascertained in all cases, the non-parametric Mann-Whitney U-test (MWU-test) was used to examine whether the observed differences were statistically significant at the 5% level. In the Mann-Whitney U-test, distributions are compared across groups.

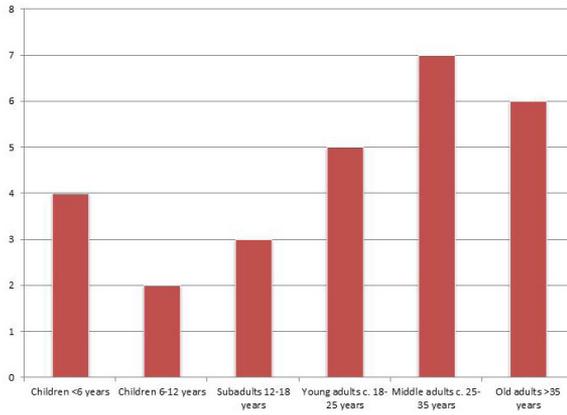
## 4 Results

### 4.1 Osteology

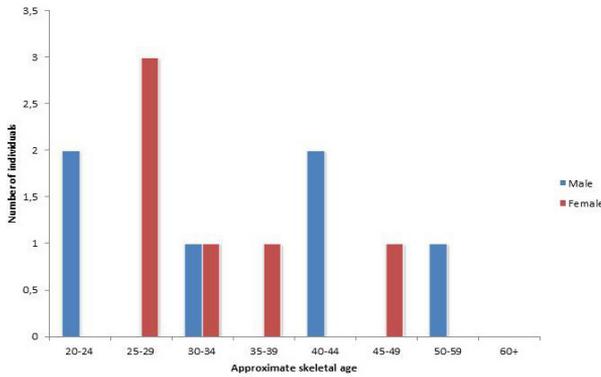
The MNI calculated for the present study is twenty-eight. Based on mandibles, tooth eruption, and dental wear, the age distribution of the sample is presented in Figure 4. It included nine children and subadults of up to 18 years of age and eighteen adult individuals of different age groups. One adult individual lacked a mandible which could be assessed to age.

Based on morphological characters of the os ilium and os pubis six females or probable females and eight males or probable males were buried. Figure 5 shows the age-at-death distribution for each sex.

Since traditional osteological methods for age estimation is known to mimic the age distribution of the reference sample and work poorly for old ages (Bocquet-Appel & Masset, 1982), twelve adult individuals could also be aged using Transition Analysis (TA) (Boldsen et al., 2002). It is evident that the oldest individuals gain substantially higher values when using TA in relation to traditional osteological methods. Point-value ages with the lowest and the highest end value is given in table 2.



**Figure 4.** Age-at-death distribution based on tooth eruption using Schour and Massler (1941), available in Hillson (1996, p. 143), and on dental wear (Miles, 1962).

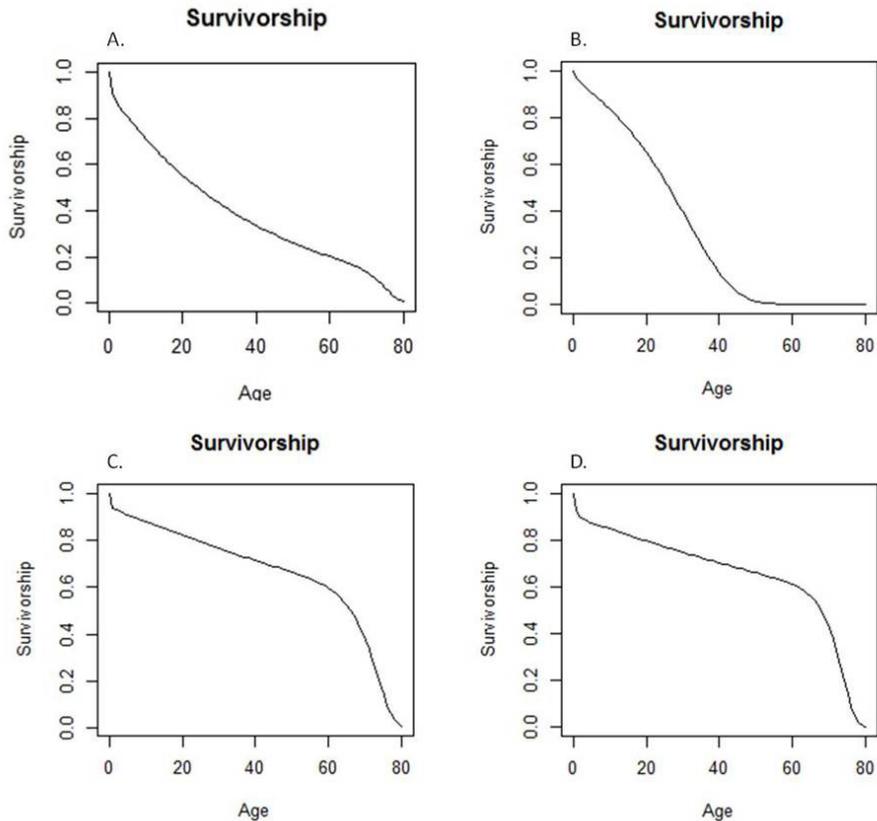


**Figure 5.** Adult age-at-death distribution divided by sex, based on the degeneration of the auricular facet as suggested by Lovejoy et al. (1985).

**Table 2.** Age-at-death distribution using *Transition Analysis*.

Point value	Low	High	Sex
20.0	15.0	26.2	M
20.0	15.0	26.2	M
20.0	15.0	28.0	F
20.0	15.0	28.0	F
20.0	15.0	28.0	F
26.5	26.5	58.0	F
35.2	15.2	69.9	M
43.0	21.8	77.3	F
75.3	45.3	90.3	M
75.3	45.3	90.3	M
72.8	30.3	90.0	F
78.1	44.9	92.5	M

There is a difference in age-at-death values between the sexes, but this difference is not statistically significant (MWU-test,  $p=0.2796$ ). The distribution suggests that the mean age at death was 33.7 years for females and 50.7 years for males. It is possible that this difference reflects the hazard of child birth in the population. The demographic pattern of Falköping 5 was further analysed using a Siler model.



**Figure 6.** Result of the Siler model for survivorship for Falköping stad 5 (a), Karataş, Turkish Bronze Age 2500–2300 BC (b) (Angel, 1969, available in Weiss & Wobst, 1973), nomadic Saami (c), and settled Saami 1796–1840 (d) (Wahlund, 1932).

The survival function of Falköping stad 5 is presented in Figure 6 and the Siler parameters in Table 3. The Siler graph of Falköping stad 5 shows tendencies towards a type I survivorship with a high mortality risk in the younger years (<15) and a high age non-specific (residual) mortality. The pattern in Falköping stad 5 is similar to that of Bronze Age Turkey; however, evidence from the Falköping stad 5 material suggests individuals there reached an older age, while also demonstrating a later onset of senescent mortality. This distinction is probably due to differences in aging methods where traditional osteological methods are unable to detect old individuals. There is a large difference, however, to both Saami populations where infant mortality is similar to that of Falköping stad 5, but with a low age-independent mortality hazard. The high number of young adults in the sample is often discussed as an “accident-bump”. This bump is a widely known phenomenon, but it is considered too detailed for paleodemographers to possibly analyze

and is usually not further investigated (Wood *et al.*, 2002). The demographic data of Falköping 5 does not resemble those of late Mesolithic Skateholm or Middle Neolithic foragers from the island of Gotland (Ahlström, 2015), who present very low child mortality rates. High juvenile mortality is primarily due to infectious disease in the world today (Black *et al.*, 2010; Roberts & Manchester, 2005). It is possible that early weaning would also influence child mortality negatively (Howcroft *et al.*, 2012). Developmental defects in tooth enamel have sometimes been discussed as a result of insufficient weaning foods (Corruccini *et al.*, 1985). However, the duration of the growth disturbance is difficult to assess (Hilson & Bond, 1997) and teeth have different predisposition for enamel defects. This relationship has therefore been questioned (Blakely *et al.*, 1994; Bennike *et al.*, 2007). The relationship between weaning and child mortality is yet not definitely settled. Traditionally, a lack of juveniles in archaeological assemblages is considered to be the result of taphonomy. However, Ahlström (2015) interprets the low number of juveniles in the Skateholm and Gotlandic material as depending on a low population density, minimizing the risk of infectious disease, *sensu lato* child mortality. The higher child mortality in the Falköping 5 material might therefore reflect a high population density or a high mobility in the area, which makes the population more at risk for infectious disease.

**Table 3.** Siler models with parameters from Falköping stad 5, Bronze Age population of Karataş (Angel, 1969, available in Weiss & Wobst (1973) and church records of Saami populations (Wahlund, 1932).

Population	Parameters for Siler model				
	$\alpha_1$	$\beta_1$	$\alpha_2$	$\alpha_3$	$\beta_2$
Falköping stad 5	1.323036e-01	1.453876e+00	2.508339e-02	4.581383e-11	2.976407e-01
Karataş	0.021103057	0.517287341	0.005052553	0.005605995	0.082126280
Nomadic Saami	3.138836e-01	5.241204e+00	6.908124e-03	1.136060e-08	2.284405e-01
Settled Saami	1.297838e-01	1.274081e+00	6.267815e-03	1.104711e-10	2.936886e-01

Only two femora from definitely different individuals could be measured for calculation of stature. Both individuals were evaluated as males based on sexual dimorphism. This classification was done by applying an iterative discriminant analysis on three different measurements of robusticity (Tornberg, 2018). The maximum femoral lengths were 44.3 and 48.9 cm correlating with a stature of 165.9 and 178.4 using Sjøvold's model (Sjøvold, 1990). The mean male stature in south Swedish Late Neolithic is 173.5 (n=8) in LNI and 173.2 in LNII-EBA (n=15) (Tornberg, 2018). Bennike (1985) reports mean stature for Denmark somewhat higher, equaling 176.2 cm in the Late Neolithic (n=50). Even if the estimates are based on different models, the results only differ marginally ( $\approx 1$  cm higher for the Trotter and Gleser 1952 model used by Bennike).

In the 152 non-molar teeth, only one cariogenic lesion could be detected, on a second lower premolar. In the 128 registered molars dental caries were present in fifteen cases, which adds up to a caries frequency of 11.7% in molars. The frequency of caries seen in all registered teeth was 5.7%, and in post-canine teeth 8%. These numbers are similar to those at the Late Neolithic-Early Bronze Age site of Abbekås, southernmost Sweden, where 6.9% of post-canine teeth were affected (Tornberg, 2013), and substantially higher than reported from Swedish Middle Neolithic skeletal assemblages (Ahlström, 2003). Dental caries appear to have been more frequent in Denmark, where a decline in affected individuals from 25% to 14.9% is reported between the Middle and Late Neolithic (Bennike *et al.*, 2007). Since the skeletal material from Falköping stad 5 is commingled, as is some of the material from Abbekås, frequencies based on individuals, such as those calculated by Bennike *et al.* (2007), have not been possible. The most common location of dental caries in Falköping 5 is interproximal (n=8) followed by the occlusal surface (n=5). Only one example of root caries and one example of a large cavity of unknown origin is represented. The sample is regarded as too small to evaluate if there are differences in the frequency of

caries and their location related to age. However, the individual suffering from root caries also exhibits one of the highest attrition scores (25/40) of the second molar among the affected teeth.

*Enamel hypoplasia* is due to disturbance of the enamel formation during tooth development in childhood, and is considered as a sign of general malnutrition and childhood illness (Hillson, 1996; King et al., 2005). Eleven teeth from eight individuals were documented with enamel hypoplasia in the Falköping 5 material. This correlates to a frequency of 28.6% of the total number of individuals of twenty-eight. The majority of individuals with enamel defects survived into adulthood, but two individuals did not survive past 12 years of age. All but one of the cases had enamel defects in the form of linear grooves, and the last case was in the form of a single pit. Canines were most commonly affected, followed by incisors. This phenomenon is common, possibly reflecting the fact that canines are more prone to develop hypoplasias, and its appearance could depend on local nutritional deficiency or lack of space in the jaw (Bennike et al., 2007). However, most individuals seem to have developed these disturbances around the age of 3–4 years, which is in accordance with site mortality.

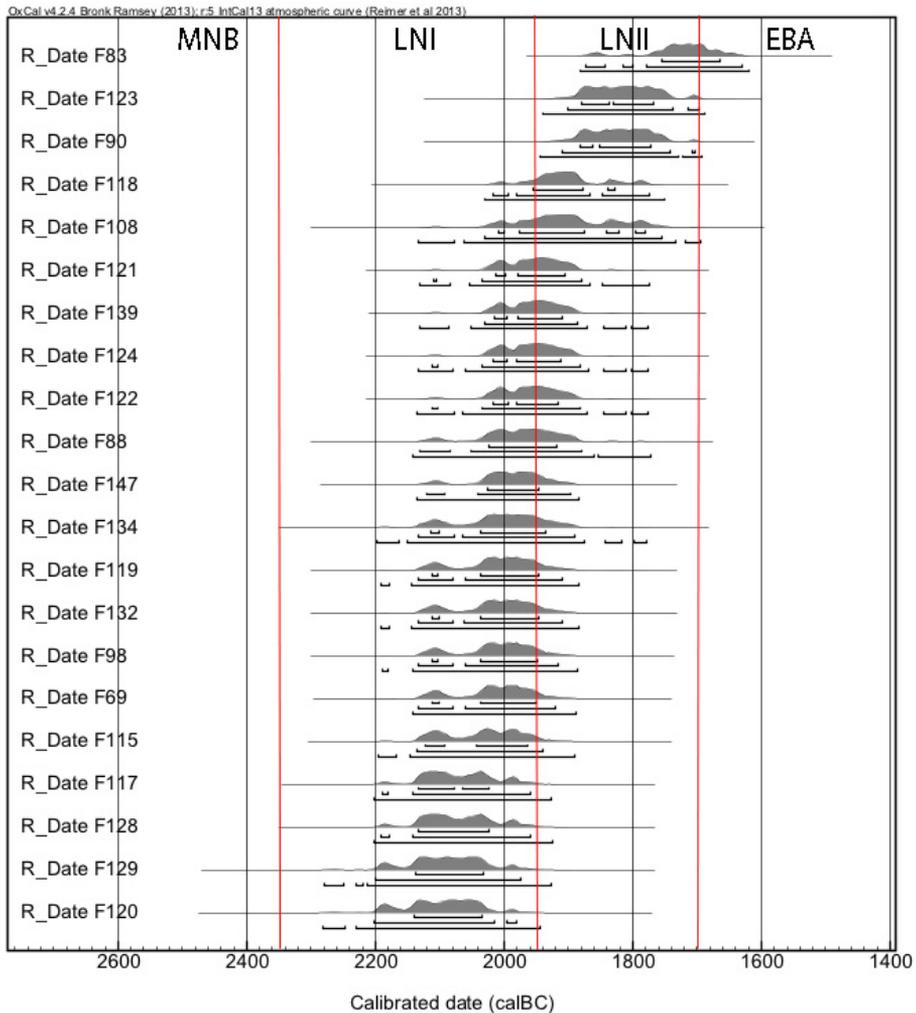
To further evaluate signs of malnutrition, the frequency of *cribra orbitalia* was registered. *Cribra orbitalia*, or pitting of the orbital roof, is generally considered a sign of iron deficiency anemia, caused by expansion of the bone marrow (Waldron, 2009). However, in contrast to genetically induced anemia, such as sickle-cell anemia and thalassemia, iron-deficiency anemia generally causes little or no expansion of the bone marrow, which is why this hypothesis has been questioned. Instead, vitamin-C- and vitamin-D-deficiency-caused hematomas have been put forward as possible explanations (Walker et al., 2009; Wapler et al., 2004). In this study, a total of nineteen frontal orbits from both sides were registered. One orbit derived from a child, three from adolescents or young adults, and the remaining from adults with different degrees of cranial suture synostosis. None of the orbits showed any signs of active or healed *cribra orbitalia*. There is no correlation between the presence of enamel hypoplasia and *cribra orbitalia* in the sample. Either individuals affected by *cribra orbitalia* lived long enough for the feature to heal out completely, or *cribra orbitalia* and enamel hypoplasia have different etiologies, with only that of enamel hypoplasia affecting the individuals in Falköping 5. The latter is considered more probable.

## 4.2 Dating

The radiocarbon analyses included in this study were conducted at the <sup>14</sup>Chrono Centre in Belfast. The Belfast lab employs more developed methods, with several cleaning steps including ultrafiltration and AMS measurements, compared to the earlier-performed conventional dating at the Laboratory in Stockholm. Therefore, the uncertainties of the new dates are smaller and the dates are here considered more reliable (Figure 7, Appendix). Furthermore, the reported C:N ratios from the samples analysed in Belfast indicate well-preserved collagen (Appendix).

A total of twenty individuals were <sup>14</sup>C dated (Figure 7, Appendix). Most of the samples were dated to the transition between Late Neolithic I and II (2sigma, 95.4%). Five of them were most probably from the Late Neolithic I (2sigma), while three individuals could be dated to the Late Neolithic II (2sigma, 95.4%) (Figure 7). Unlike previous dates, no Middle Neolithic date was observed. The <sup>14</sup>C analyses suggest a use-time of the grave between about 100 and 550 years (2sigma, 95.4%). The main phase of the burials is concentrated to about 2000 cal BC. The series indicates a continuous use, even though two or three shorter phases might also be possible.

The osteological results indicate successive burials. The distribution of the <sup>14</sup>C-dated bones was investigated stratigraphically and spatially in ArcGIS (10.1). Over all, there was no apparent pattern of where the skeletal remains were found according to their <sup>14</sup>C dates, although the three latest buried individuals (F83III:1, F90 and F123) were found in the upper layers (Appendix, Weiler, 1994, pp. 12, 15).



**Figure 7.**  $^{14}\text{C}$  dates of the twenty individuals sampled from Falköping stad 5. OxCal v.4.2.4 Bronk Ramsey (2013); r5 IntCal13 atmospheric curve (Reimer et al. 2015). Red lines mark the different periods: MNB: Middle Neolithic B, LNI: Late Neolithic I, LNII: Late Neolithic II and EBA: Early Bronze Age.

### 4.3 Carbon and Nitrogen Stable Isotopes for Dietary Reconstruction

In this study, teeth from twenty-one individuals of different age and sex were sampled (Table 1, Appendix). In contrast to bones, the turnover of tooth dentine is insignificant and therefore corresponds to the formation time of the tooth root. The teeth included in this study offer an average of the food intake during the childhood and early youth (Hillson, 1996, p. 155). No quantitative diet reconstruction was possible due to the lack of relevant reference samples. The available  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  measured in animals and plants are either dated to other time periods or originate from other regions, which might have very different subsistence strategies and environmental conditions. However, to be able to include also the carbohydrate

and fat contribution to the diet, the results of  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  analyses of dentin collagen are presented and discussed, along with the  $\delta^{13}\text{C}$  data of enamel apatite (Appendix, Table 4).

The  $\delta^{15}\text{N}$  values of the four deciduous teeth, mean value of  $10.4 \pm 0.4\text{‰}$  (1SD), were significantly higher than those of the permanent teeth ( $n=17$ ), mean value of  $9.3 \pm 0.8\text{‰}$  (1SD) (MWU-test,  $p=0.031$ ). These elevated values are likely caused by breastfeeding and deciduous teeth were therefore excluded from further evaluation regarding dietary composition. The roots of the first molars begin forming at the age of three years and thus could also be affected by breast feeding (Hillson, 1996). However, no statistically significant increase of the  $\delta^{15}\text{N}$  values could be noted. Therefore, the first molars are included in the diet analysis.

**Table 4.** Summary statistics of light stable isotope data from Falköping stad 5, with and without the outlier (collagen apatite spacing) F122.

Category	N	Mean $\delta^{15}\text{N}_{\text{Collagen}} \pm 1$ SD (‰)	Mean $\delta^{13}\text{C}_{\text{Collagen}} \pm 1$ SD (‰)	Mean $\delta^{13}\text{C}_{\text{Enamel}} \pm 1$ SD (‰)	Collagen-apatite spacing $\pm 1$ SD (‰)
All sampled teeth	21/20	$9.5 \pm 0.8$	$-20.8 \pm 0.4$	$-14.6 \pm 0.9/-14.7 \pm 0.7$	$6.2 \pm 0.8/6.1 \pm 0.5$
All excluding deciduous teeth	17/16	$9.3 \pm 0.8$	$-20.9 \pm 0.3$	$-14.5 \pm 1.0/-14.7 \pm 0.7$	$6.3 \pm 0.9/6.2 \pm 0.5$
Female	5	$9.5 \pm 0.9$	$-20.9 \pm 0.5$	$-14.8 \pm 0.8$	$6.1 \pm 0.5$
Male	11/10	$9.3 \pm 0.8$	$-20.9 \pm 0.3$	$-14.3 \pm 1.1/-14.6 \pm 0.7$	$6.6 \pm 1.0/6.3 \pm 0.5$

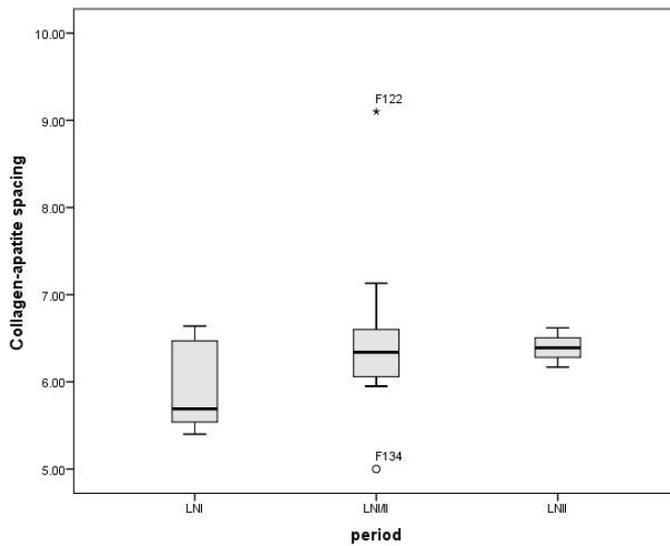
The average  $\delta^{15}\text{N}$  of  $9.3 \pm 0.8\text{‰}$  and the  $\delta^{13}\text{C}$  mean value of  $-20.9 \pm 0.3\text{‰}$  (1SD) in dentin collagen (Table 4) reflect a terrestrial diet (Schoeninger et al., 1983). The mean  $\delta^{13}\text{C}$  value in apatite is  $-14.5 \pm 1.0$  (1SD). The relatively low  $\delta^{15}\text{N}$  values indicate a minimal consumption of freshwater fish and no reservoir effect is suspected. The standard deviation of the  $\delta^{15}\text{N}$  values mirrors their high variation, while the standard deviation of the  $\delta^{13}\text{C}$  in collagen is relatively low (Table 4). There is a slight difference, although not statistically significant (MWU-test,  $p=0.441$ ), of  $\delta^{15}\text{N}$  between the sexes, showing lower  $\delta^{15}\text{N}$  values and higher collagen apatite spacing for males (Table 4).

The mean value of the collagen-apatite spacing is  $6.3 \pm 0.9\text{‰}$  (1SD). However, in this case there is an outlier, F122, with a very high collagen-apatite spacing ( $9.1\text{‰}$ ) (Figure 8). If this individual is excluded the mean value and standard deviation of the collagen-apatite spacing are slightly lower (Table 4). In both cases the collagen-apatite spacing results correspond better to herbivores and omnivores than carnivores (Lee-Thorpe, 1989, p. 590), suggesting a substantial intake of plant foods such as cereals and vegetables.

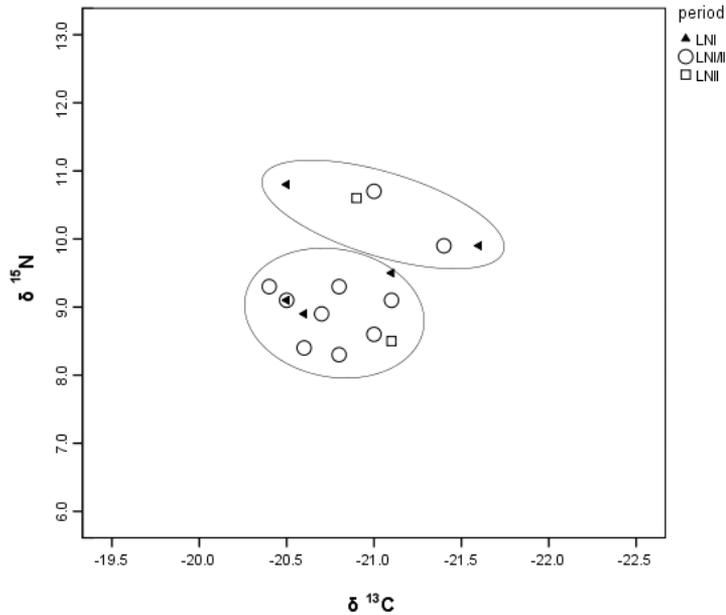
When the collagen-apatite spacing is plotted in three different phases, two outliers appear (Figure 8). A probable male who died at the age of 40–50 years, F122, shows the highest collagen-apatite spacing. The same individual also has a rather low  $\delta^{15}\text{N}$  value ( $8.3\text{‰}$ ) (Figure 8, Appendix), which could indicate a high intake of plant food. The sample with the lowest collagen-apatite spacing ( $5\text{‰}$ ), F134, belongs to a young adult (Figure 8; Appendix). If these two outliers are omitted, some slight differences in the collagen-apatite spacing over time can be observed, with the lowest median value in the earliest phase and the highest median value in the later phases (Figure 8).

Figure 9 shows two data clusters, which probably reflect different diets. The smaller group has  $\delta^{15}\text{N}$  values indicating a higher consumption of protein from a higher trophic level than the larger group. These differences do not correspond to sex, strontium isotopes, or radiocarbon dating. It might reflect differences in subsistence strategies or in social status.

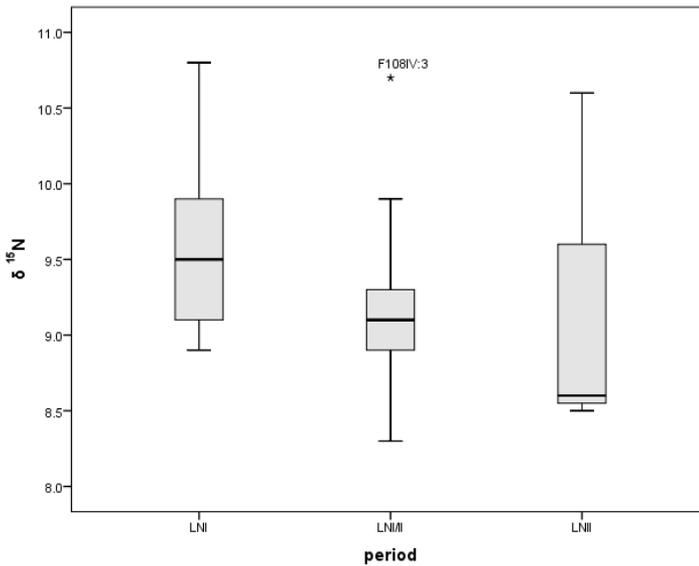
There is no obvious correlation between the  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values in collagen and the  $^{14}\text{C}$  dates (Figure 9), and the sample size in some of the phases are too small for any statistical significance tests. However, a small tendency for higher  $\delta^{15}\text{N}$  values can be observed in the individuals buried in the first part of the Late Neolithic (Figure 10).



**Figure 8.** Collagen-apatite spacing from the 17 individuals in Falköping stad 5, included in the diet investigation. Boxplot with line: median, box: 25<sup>th</sup>-75<sup>th</sup> percentile, whisker: ca 95% of the data. LNI: Late Neolithic I, LNII: Late Neolithic II.



**Figure 9.**  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values in collagen from the 17 sampled teeth from Falköping stad 5, included in the diet investigation. LNI: Late Neolithic I, LNII: Late Neolithic II.



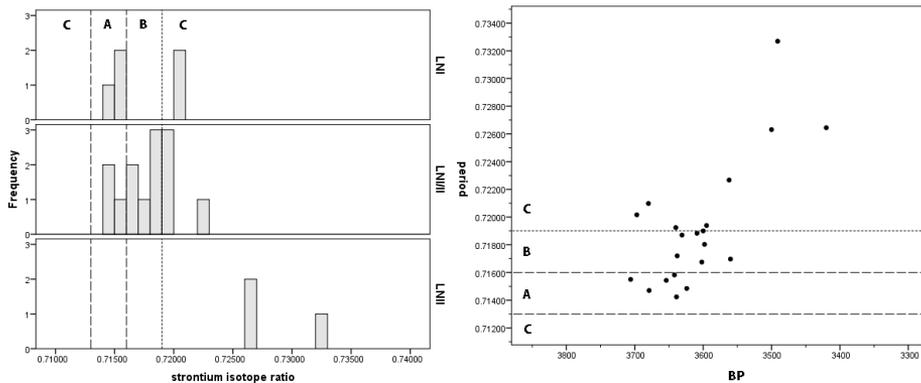
**Figure 10.**  $\delta^{15}\text{N}$  values in collagen from the seventeen individuals in Falköping stad 5, included in the diet investigation. Boxplot with line: median, box: 25<sup>th</sup>-75<sup>th</sup> percentile, whisker: ca 95% of the data. LNI: Late Neolithic I, LNII: Late Neolithic II.

#### 4.4 Results of Strontium Isotope Analysis

Based on earlier and ongoing research, the isotopic signal of the bio-available in Falbygden is suggested to range from 0.713 to 0.716 (marked with dashed lines in figures 11, 12, 13 and 15), and in the limestone area where Falköping stad 5 is located ratios around 0.714 are very likely (Blank et al., 2018; Blank & Knipper, in press; Sjögren et al., 2009; Sjögren & Price, 2012). In a nearby passage grave, Falköping stad 3, measurements from two rodents showed ratios of 0.714 (Sjögren et al., 2009). Ratios ranging between 0.719 and 0.726 are interpreted here as signals which could originate from different locations in the surrounding Precambrian areas in inland-western Sweden, while even higher ratios can be expected in the eastern or northeastern part of Sweden (Åberg & Wickman, 1987, pp. 36–37; Eriksson et al., 2016; Lindström, 2009; Price et al., 2017; Sjögren et al., 2009). Ratios between 0.717 and 0.719 (marked with dashed lines in figures 11, 12, 13 and 15) are more difficult to interpret and several explanations are plausible. The ratios are found in areas about 30 km south and 20 km northwest of Falbygden but can also be expected for areas surrounding Falbygden (Blank et al., 2018; Blank & Knipper, in press; Frei, 2009; Sjögren et al., 2009; Sjögren & Price 2012). However, these ratios could also be mixed signals from Falbygden and the surrounding Precambrian areas for reasons discussed in more detail below. In this paper, the clearly delimited Cambrosilurian area of Falbygden is defined as local, whereas both the closest surrounding Precambrian region and areas of further distances are considered non-local. Thus, movements within the 50 × 30 km extended Falbygden region, as well as movements between Falbygden and other areas with similar strontium isotope signals, cannot be detected.

In the following section, the strontium isotope ratios incorporated during childhood and early youth of the buried individuals are discussed. The terms local and non-local refer here to isotope signals and not to the origins of individuals (see above and discussion). In four cases, deciduous teeth (dpm) are included, which gave  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios of between 0.717 and 0.726 (Appendix). The enamel of these teeth starts to develop before birth and is completely crystallized at the age of 6 to 9 months (Hillson, 1996). Hence, the strontium isotope ratio also mirrors the whereabouts of the mother carrying the unborn/infant child. Of all

the sampled individuals only six (29%), show a local signal with signals close to 0.715 (mean  $0.7150 \pm 0.0005$ ) while seven (33%) fall into the more ambiguous range from 0.717 to 0.719, and eight individuals (38%) most likely spent part of their childhood outside of the sedimentary area of Falbygden. In three individuals (F83III:1, F90 and F123), ratios higher than 0.726 were measured. F123, a probable female, who died when she was over 40 years of age, has a very high ratio (0.733), which is not a likely signal from western Sweden. The frequency of buried individuals with non-local signals is higher in this grave than what is generally found in the Late Neolithic megalithic population of Falbygden (Locals: 42%, Ambiguous: 29%, Non-locals: 29%, Blank & Knipper, in press).



**Figure 11.** Strontium isotope ratios of the buried individuals in Falköping stad 5 in chronological order (histogram and a scatter plot). A: Local  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios, B: non-local/mixed  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios, C: non-local  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios, see text above. The local and non-local signals of Falbygden are based on earlier and ongoing research. LNI: Late Neolithic I, LNII: Late Neolithic II.

There is no apparent correlation between the strontium isotope ratios and the  $^{14}\text{C}$  dates in the first phase, when most of the individuals were buried in this grave (Figure 11). As can be observed in figure 10, the youngest burials—the individuals dated to the Late Neolithic II (F123, F83III:1 and F90)—have significantly higher (MWU-test,  $p=0.002$ ) strontium isotope values than the rest of the individuals investigated (Appendix). The adult man (F83III:1) and the child (F90) have very similar strontium isotope ratios and  $\delta^{15}\text{N}$  values, which could indicate a common origin. A plausible explanation is that these three individuals belong to a later burial phase associated with a non-local group.

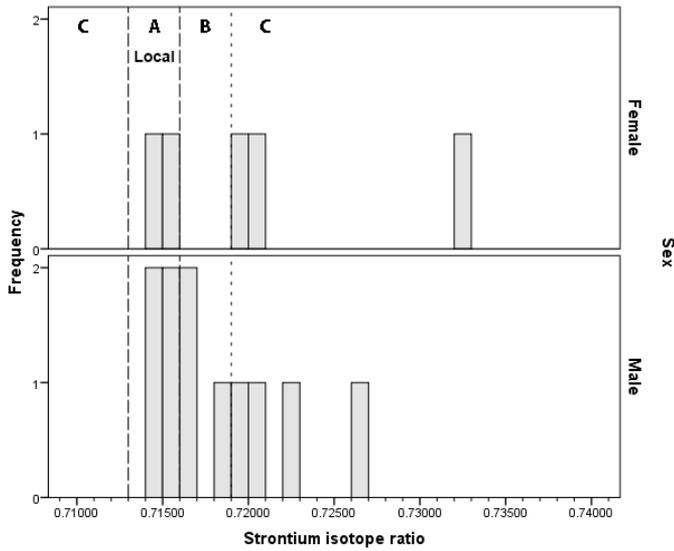
As can be observed in Figure 12, there is no correlation between sex and strontium isotope ratios. In figure 12, it seems like there are no women with ratios in the range between 0.716 and 0.719, but a more accurate description is that there are no adults of female sex with these ratios. However, the ratios from two children where enamel formed in utero or as infants fall into this range, and the ratio 0.7263 is also represented in the enamel of another child in the sample (Figure 13). At such an age, babies share the isotopic signal of their mothers at that specific time.

## 5 Discussion

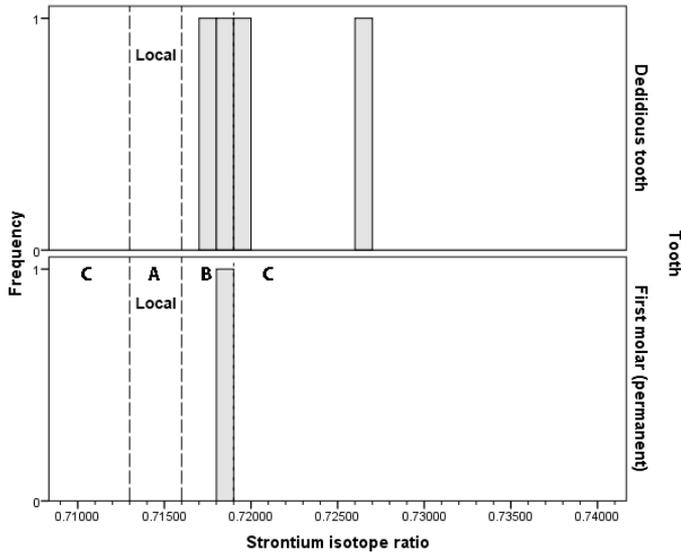
In this part, the results obtained from the gallery grave Falköping stad 5 are placed within their wider geographical and chronological framework.

### 5.1 Time of Use

Previous research revealed that dolmens and passage graves were built over a relatively short period at the transition between the early and the middle Neolithic, 3300–3000 cal BC, in the cultural setting of the



**Figure 12.** Histogram of strontium isotope ratios compared to sex, Falköping stad 5. A: Local  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios, B: non-local/mixed  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios, C: non-local  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios, see text above. The local and non-local signals of Falbygden are based on earlier and ongoing research.



**Figure 13.** Histogram of strontium isotope ratios of children and juveniles with unknown sex, Falköping stad 5. A: Local  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios, B: non-local/mixed  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios, C: non-local  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios, see text above. The local and non-local signals of Falbygden are based on earlier and ongoing research.

Funnel Beaker Culture (Persson & Sjögren, 1995, 2003, 2011). The chronology of the gallery graves is still not addressed in a sufficient way, but indications of Middle Neolithic gallery graves have been suggested (Algotsson, 1996; Blank, 2016). There have been several attempts to date the different kinds of gallery graves found in Sweden by analysing their construction, but this method has turned out to be complicated (Anderbjörk, 1932; Johansson, 1961; Montelius, 1905, etc). A previous study of the use and reuse of megalithic graves in Falbygden, based on new  $^{14}\text{C}$  analyses and relative dating of artefacts revealed that the most intense period of use for the gallery graves, as well as the most intense period of reuse of passage graves, was the second half of the Late Neolithic (Blank, 2016). Most of the Danish stone cists seem to have been in use in the transition between Late Neolithic I and II and in Late Neolithic II, based on dagger types found in the graves (Ebbesen, 2004, p. 23).

New radiocarbon dating of human remains show that gallery graves in Falbygden were used for successive burials into the Early Bronze Age period II/III (Blank, 2017). Moreover, a relatively large quantity of  $^{14}\text{C}$  dates of skeletal remains from Scania, southern Sweden, show that gallery graves were intensely used at least into the Early Bronze Age period II in this region as well (Bergerbrant *et al.*, 2017; Tornberg, 2017).

In the second part of the Scandinavian Late Neolithic, daggers also become more common and metal objects begin appearing in graves in south-west Sweden (Apel, 2001; Vandkilde, 1996; Weiler, 1994). The lack of metal objects and later dagger types, along with the  $^{14}\text{C}$  dates, indicates that this grave was used for a rather limited period around 2000 cal BC with a few individuals buried later in the beginning of LNII. No slate pendants, which are very common in gallery graves in southern Scandinavia, were found in this grave. Anderbjörk (1932, p. 32) argues that slate pendants can be dated to the later part of Late Neolithic as they occur with the later dagger types. Falköping stad 5 can thus be considered to be a rather early gallery grave (Late Neolithic I) with no burials later than the Late Neolithic II. Furthermore, there is nothing that suggests that this is a Middle Neolithic grave, which one could suspect based on the earlier radiocarbon dates.

Considering the  $^{14}\text{C}$ -dates, the gallery grave appears to have been continuously used, although use in two or three different phases in close succession is also possible. The majority of the burials are dated to LN I and the transition between the LNI–LNII. This commingled bone material indicates successive use, with skeletal remains moved to make way for new burials. On the other hand, the three individuals dated to Late Neolithic II were all found in the upper layers (see above). In Falbygden, several phases of burials in numerous gallery and passage graves have been observed and discussed (Ahlström, 2009; Sjögren, 2003; Weiler, 1997). The individuals included in the latest burial phase all have strontium isotope signals distinct from the others, suggesting they may have travelled a long distance to reach the area. Such evidence could indicate an influx of people from new areas. Possibly a non-local group settling and reusing the grave, or non-local people integrating to the group using the grave.

## 5.2 Health and Demography

The Falköping stad 5 gallery grave displays a high child mortality rate, with one third of the skeletons representing individuals who did not reach an adult age. Even though this is suggested to be an expected frequency (Lewis, 2007), it has recently been questioned for prehistoric populations (Ahlström, 2015). Further, half of the adults that could be aged using transition analysis ( $n=6$ ) died before the age of 30, and the majority of these (4/6) were female. The high female mortality during childbearing years is probably due to hazards in relation to childbirth. Half of the adult males, as well as females who survived their childbearing years, lived into their seventies. A high number of juveniles within a sample is often associated with a population increase (Wood *et al.*, 1992). Since the risk of infectious disease and childhood mortality are closely connected, Ahlström (2015) suggests that the invisibility of children in Stone Age materials does not merely reflect taphonomic loss, but also a low population density. It is probable that low visibility of children in the material is affected by both. The high childhood mortality in the Falköping stad 5 gallery grave might reflect a rather high population density and/or mobility in the area during the Late Neolithic. Weiler (1994, p. 66) suggests that the sex and age distribution in the grave indicates a family grave, and demographic calculations made by Grandell (in Iregren, 1977, p. 62ff) have been used to support this idea. This assessment is reasonable; however, considering a seemingly high population density and usage under

an apparently short time span, one could argue it is more likely to be a grave for individuals living in the vicinity, and while it is possible that some individuals did belong to the same family, it is unlikely they all belonged to one specific family. Further, there remains the question of how one defines a family. The definition of a Neolithic family has been discussed, and the characterisation of megalithic graves as family graves has been rejected by Ahlström (2009, p. 135ff.), who argues that the large size variation in Falbygden Middle Neolithic passage graves indicates that a number of families joined together in the construction and use of the grave. Similar size variation is also seen in Late Neolithic gallery graves.

Growth and stature are closely connected to health. Generally, osteologists and archaeologists have suggested that stature increases in the south Scandinavian Late Neolithic. This conclusion is partly confirmed by Tornberg (2018), who states that stature is high in the Late Neolithic, but this substantial increase in stature is associated with the Battle Axe Culture in Middle Neolithic B. The two males from Falköping stad 5 measured 165.9 and 178.4 cm in stature using Sjøvold's model (Sjøvold, 1990), which is considered consistent with a mean male stature in the south Swedish Late Neolithic of 173.5 (n=8) in LNI and 173.2 in LNII-EBA (n=15) (Tornberg, 2018). It is difficult to draw any conclusions regarding health based on only two individuals, since the genetic component of stature becomes too dominant; however, there is no evidence of growth stunting, indicating sufficient nutrition and moderate disease rates during adolescence when much of adult stature is determined.

The frequency of enamel hypoplasia is relatively high (28.6%) in relation to the Late Neolithic-Early Bronze Age locality of Abbekås in southern Sweden (15%) (Tornberg, 2013), but lower than in Middle and Late Neolithic Denmark (40%) (Bennike et al., 2007). The location of the enamel defects shows that nutritional stress or illness commonly affected children around the age of 3–4, often attributed to an increased risk of diseases associated with weaning. However, it might also depend on tooth morphology, where earlier enamel hypoplasia is undetectable macroscopically (Lewis, 2007). However, most of the individuals exhibiting enamel hypoplasia (6/8) survived into adulthood. It is probable that the high child mortality, high mortality among females of reproductive age, and the frequency of enamel hypoplasia together display a population at high risk for infectious disease due to a relatively high population density, and possibly also at risk of infections associated with close contact with animals (Roberts & Manchester, 2005, p. 23).

There is no evidence of Cribra orbitalia. Bennike (1985) states that cribra orbitalia is present in approximately 50% of the children and 10–20% of the adults in prehistoric Denmark. In the Abbekås material, 7.7% of the individuals were affected (Tornberg, 2013). The aetiology of cribra orbitalia is somewhat unclear, but iron deficiency anaemia and/or vitamin C or D deficiency are probable causes. Although it is probable that the pathological features of cribra orbitalia are multi-causal, Tornberg in this study favours the vitamin C/D deficiency hypothesis since bone-marrow hypertrophy related to iron-deficiency is low. It would be beneficial for future research to further investigate a possible correlation between cribra orbitalia and other signs of vitamin C and vitamin D deficiency. However, with unclear aetiology of cribra orbitalia, it seems to have been entirely absent in Falköping stad 5.

### 5.3 Diet and Subsistence

According to previous research (Blank, in press; Sjögren & Price, 2013b; Sjögren, 2017), agriculture was already well established in Falbygden during the Middle Neolithic. Pollen analysis indicates that pasture land increased during the Late Neolithic in southern Scandinavia (Holm et al., 1997, p. 216). Furthermore, shafthole axes, which appear in the Late Neolithic period, are associated with the clearance of woodland (Holm et al., 1997, p. 216). During the Scandinavian Late Neolithic, an increased population density can be observed, which often has been interpreted as a consequence of an intensified agriculture, in turn resulting in the spread of the gallery graves in the landscape. Gallery graves in Falbygden were placed in the same areas as the passage graves but are situated in other areas too providing a higher variation of the topographical distribution of the graves.

Evidence of agricultural activities in Late Neolithic Falbygden includes, for example, flint tools used for harvesting and a few seed impressions on ceramic vessels (Hjelmquist, 1955; Weiler, 1994). Animal bones in

gallery graves are quite common and mainly derive from domesticated animals such as pigs, cattle, and goats/sheep. These are also the dominant species found in the Middle Neolithic passage graves and settlements (Sjögren et al., in press; Sjögren & Price, 2013b; Sjögren, 2017). Fish remains from the settlements, on the other hand, have been scarce, even though small bones often have been preserved in the calcareous soils (Sjögren, 2017, p. 297; Sjögren et al., in press). Although rare, two fish hooks have been found in a Middle and a Late Neolithic megalithic grave in the area of Falköping stad (SHM: 4840:29-32, SHM: 4034: a). In the Falköping stad 5 grave, a few pike bones were found. These bones might belong to the Late Neolithic period, but they could also be a result of later animal activity since bones from two foxes were identified (Weiler, 1977, p. 54). It is likely that fish was consumed, even if only marginally as indicated by the low  $\delta^{15}\text{N}$  values. Bones from different birds have been excavated at a Middle Neolithic settlement not far from Falköping stad, although they did not represent a large part of the bone material (Sjögren et al., in press). Today, the Falbygden area is known for its rich birdlife and the many small lakes and streams were probably also a favourable environment for birds during the Neolithic. Some consumption of birds and eggs would be expected.

The mean values of  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  (9.3‰ and -20.9‰) measured in collagen in buried individuals in Falköping stad 5 reflect a terrestrial diet and are similar to values in other Late Neolithic individuals, both from Falbygden and from the island of Öland, in southern Sweden (Blank, in press; Eriksson et al., 2008). Unlike in Öland, in Falbygden the  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  values from the earlier megalithic population are similar to the Late Neolithic individuals (Blank, in press; Eriksson et al., 2008; Sjögren & Price, 2013b). Previous studies of the Middle Neolithic population in Falbygden revealed rather homogenous  $\delta^{13}\text{C}$  values around -21‰ and  $\delta^{15}\text{N}$  values around 10.5‰, which can be expected for an inland population with a terrestrial diet (Blank, in press; Hinders, 2011; Lidén, 1995; Sjögren & Price, 2013b). These values are consistent with other Middle Neolithic megalithic populations from southern Sweden, Denmark, and Germany where  $\delta^{15}\text{N}$  values between 10 and 11‰ and  $\delta^{13}\text{C}$  values around -20 to -21‰ were observed (Sjögren, 2017, p. 297).

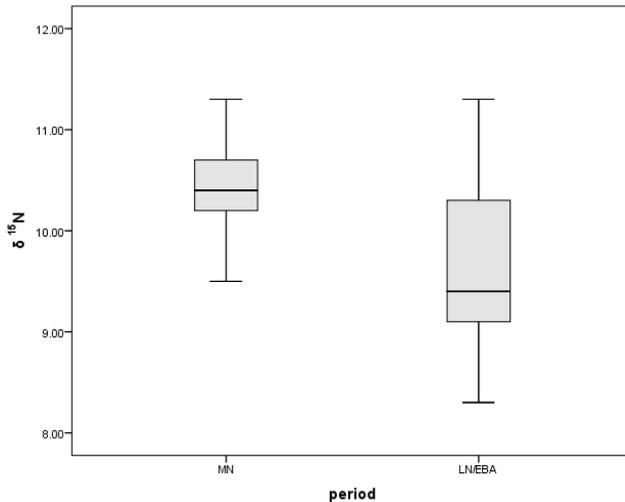
**Table 5.** Summary statistics of light stable isotopes from megalithic populations in Falbygden. MN: Middle Neolithic, LN: Late Neolithic, EBA: Early Bronze Age.

Period	Location	Bone element	N	Mean $\delta^{15}\text{N}$ (‰) 1 SD	Mean Collagen apatite spacing (‰) 1 SD	Ref
MN	Falbygden	teeth	21	10.4±0.4	6.2±0.8	Hinders 2011; Sjögren, Price 2013b
MN	Falbygden	teeth	8/5	10.4±0.5	6.2±0.2	Blank in press
LN/EBA	Falbygden	teeth	16	9.9±0.7	6.1±0.7	Blank in press
LN	Falköping stad 5	teeth	17/16	9.3±0.8	6.3±0.9/ 6.2±0.5	This study

The tendency of higher  $\delta^{15}\text{N}$  values and lower collagen-apatite spacing observed in the Falköping 5 material in the earlier burials could indicate a greater consumption of protein from higher trophic levels and a lower intake of plant food than in the later part of the Late Neolithic. However, in general the collagen-apatite spacing of the individuals from Falköping stad 5 is similar to findings in Middle Neolithic megalithic populations and other Late Neolithic/Early Bronze Age individuals from Falbygden (Table 5). The high standard deviation of the  $\delta^{15}\text{N}$  values in Falköping stad 5 corresponds better to the LN/EBA than to the MN values of Falbygden (Table 5). In figure 14, the  $\delta^{15}\text{N}$  values from Falköping stad 5 are presented with previous results associated with permanent teeth from megalithic graves in Falbygden (Blank, in press; Hinders, 2011). The  $\delta^{15}\text{N}$  values are more varied and lower in the Late Neolithic than in the Middle Neolithic—a difference that is significant (MWU-test,  $p=0.003$ ).

The lower  $\delta^{15}\text{N}$  values during the Late Neolithic compared to the Middle Neolithic period could indicate a decrease in the intake of animal-derived foodstuffs, such as meat or dairy products, or an increased consumption of protein from a lower trophic level, such as plant food. This interpretation is however contradicted by the fact that the plant food intake does not seem to increase if the collagen-apatite spacing is taken into consideration. Instead, similar values can be observed during the Late Neolithic and the Middle Neolithic. Caries frequency is slightly higher in Falköping stad 5 than in contemporary Scania (Tornberg, 2013, 2017) and substantially higher than in Middle Neolithic Falbygden (Ahlström, 2003). The caries

frequency supports an increased reliance on carbohydrates, but could possibly also depend on hereditary factors or different tooth brushing.



**Figure 14.**  $\delta^{15}\text{N}$  from megalithic individuals in Falbygden (teeth). Boxplot with line: median, box: 25<sup>th</sup>- 75<sup>th</sup> percentile, whisker: ca 95% of the data. MN: Middle Neolithic, LN/EBA: Late Neolithic/ Early Bronze Age.

Analysis of ancient protein preserved in dental calculus from six individuals in Falköping stad 5 provides evidence supporting dairy consumption (Fotakis et al., in preparation). A milk protein, beta-lactoglobulin, was previously identified in archaeological dental calculus dating from the Bronze Age onwards (Warinner et al., 2014). The oldest milk residues in Sweden were found in a ceramic vessel dated to the Early Neolithic (4000–3350 cal BC) (Isaksson & Hallgren, 2012). In Falbygden, traces of milk products have been found in Middle Neolithic pottery (Kaldhussæter Lindboek, 2014). The result from Falköping stad 5 is amongst the earliest evidence for direct consumption of dairy in Sweden (Fotakis et al., in preparation). Currently, in individuals from Falköping stad 5, there is no molecular evidence supporting the presence of the genetic mutation responsible of lactase persistence (LP), i.e. the ability for adults to digest lactose (a milk sugar). This trait emerged as a consequence of a relatively recent genetic mutation, supposedly related to the practice of dairying (Sverrisdóttir et al., 2014; Hollox et al., 2001; Itan et al., 2009; Bersaglieri et al., 2004; Leonardi et al., 2012; Ségurel & Bon 2017), and so far absent or detected at low frequency in the Early to Middle Neolithic (Burger et al., 2007; Malmström et al., 2010; Allentoft et al., 2015). The timing and circumstances leading to the selection of traits linked to LP is still not fully understood, but increased access to liquids (Hollox et al., 2001) and the important source of D-vitamin (Itan et al., 2009) have been put forward as explanations. However likely to have been suffering from some stomach ache, there are examples of non LP regular milk-drinkers as well (Ségurel & Bon, 2017). Lactose reduces when milk is processed into cheese or yoghurt (Leonardi et al., 2012), which were probably also the first kinds of dairy consumed. It is possible that the evidence of dairy consumption in all sampled individuals is a sign of a surplus in dairy products related to a change towards a focus on secondary products, i.e. *the Secondary Products Revolution* (Sherratt, 1981). The ceramic ware of the Late Neolithic is substantially different from the pottery from the earlier periods. Hulthén (2013) argues that Late Neolithic pottery is adapted for keeping liquids cold and is suitable for souring them. If *cribra orbitalia* is due to vitamin D deficiency, it is interesting that there is no registered case in the population, where dairy, rich in vitamin D, was been consumed on a regular basis.

The lower  $\delta^{15}\text{N}$  values found in individuals from Falköping stad 5 than those associated with earlier populations could indicate a greater dependence on cattle than pigs, as pigs in general eat from a higher

trophic level than cattle. A greater dependence on cattle could indicate a focus on secondary products such as milk or blood (Evans-Pritchard, 1937, p. 223ff.; Sherratt, 1981). This suggestion would, however, have to be confirmed by isotope analyses on pig and cattle remains themselves. However, the previously analysed sheep, cattle, and pig remains from the Middle Neolithic show similar  $\delta^{15}\text{N}$  values (Sjögren, 2017, p. 299). The levels of  $\delta^{15}\text{N}$  could also be affected by differences in agro-pastoral strategies. The  $\delta^{15}\text{N}$  values of the animals can change depending on how they are held and fed, and the  $\delta^{15}\text{N}$  values of crops can vary depending on if and how the fields are manured and used, etc.

The higher variability during the Late Neolithic could indicate specialisation. The distribution of gallery graves in different topographical areas could also indicate increased variation in subsistence strategies. However, it is important to acknowledge that nitrogen isotope fractionation is complex and not completely understood, and it seems like there is a rather high variability of  $\delta^{15}\text{N}$  values among individuals with a similar diet (Deniro & Schoeniger, 1983; O'Connell *et al.*, 2012). In this particular study differences in fractionation could not be the only explanation since the same variation is not seen in the Middle Neolithic population. The higher variability could indicate an increased stratification of society where the access to different foods varied in different social strata or a generally higher human mobility with influx of people with different backgrounds (Blank & Knipper, *in press*; Tornberg, 2017).

## 5.4 Human Mobility

The majority (71%) of the buried individuals have non-local strontium isotope signals, i.e.  $^{87}\text{Sr}/^{86}\text{Sr}$  signals not present in the Cambrosilurium area of Falbygden (Appendix; Figure 12). This discrepancy is probably due to a high level of mobility among the individuals buried in Falköping stad 5. Since the samples reflect the geological signal associated with childhood locales, the individuals with non-local signals might only have been brought to the Falköping stad area for burial. However, it seems most likely that the megalithic graves of Falbygden were used by local groups living in the vicinity of the graves (Sjögren, 2003; Sjögren *et al.*, *in press*; this study). In that case, non-local signals would represent people who moved into the area in their younger years and settled for different reasons, including exogamous marriage alliances with groups from outside of Falbygden. Marriage alliances are an effective way of maintaining networks between different groups as well as lowering the risk of inbreeding. Similar propositions have been suggested in published work on the Middle Neolithic population (Sjögren *et al.*, 2009). As in previous studies of both the Middle and Late Neolithic, there is no correlation between sex and non-local strontium isotope signals indicating any specific marriage system (Blank & Knipper, *in press*; Sjögren *et al.*, 2009).

The strontium isotope signals ranging between 0.716 and 0.719 could be explained by individuals moving in from different locations outside or at the outskirts of Falbygden (Sjögren *et al.*, 2009). It can also be a result of local individuals consuming non-local food, particularly plant food, since plant food is the main contributor to human uptake of strontium (Bentley, 2006). However, the favourable conditions for agriculture with calcareous soils and the easy access to water do not support a large import of plant food. Ratios within this range could also be a result of repeated movement in and out of Falbygden. One reason for such movements could be transhumance—that is, herding of cattle and sheep/goat between different grazing lands between seasons. The distance from Falköping stad 5 to the outskirts of Falbygden is between 6 and 15 km depending on direction. It is possible that seasonal herding was performed, although transhumance can only influence the strontium isotope signal if individuals consumed foodstuffs that were derived along the way and participated in these activities from early childhood. The suggestion of young cattle herders during prehistory has been brought forward by Welinder (1998, p. 192). However, to obtain a strontium isotope ratio above 0.718 you would need to consume a substantial part of your food stuff from the Precambrian areas. Hence, there could have been a lot of movement between the two geological areas that cannot be detected by strontium isotope analysis.

Ratios between 0.719 and 0.726 can be expected in large parts of the Precambrian areas surrounding Falbygden, but are also found in areas further away. Similar ratios are, for example, found in Norway and eastern Sweden (Lövendahl *et al.*, 1990; Price *et al.*, 2015; Wilhelmson & Ahlström, 2015). The individual with a strontium isotope ratio of 0.733 is not likely to originate from western Sweden and ratios above 0.726

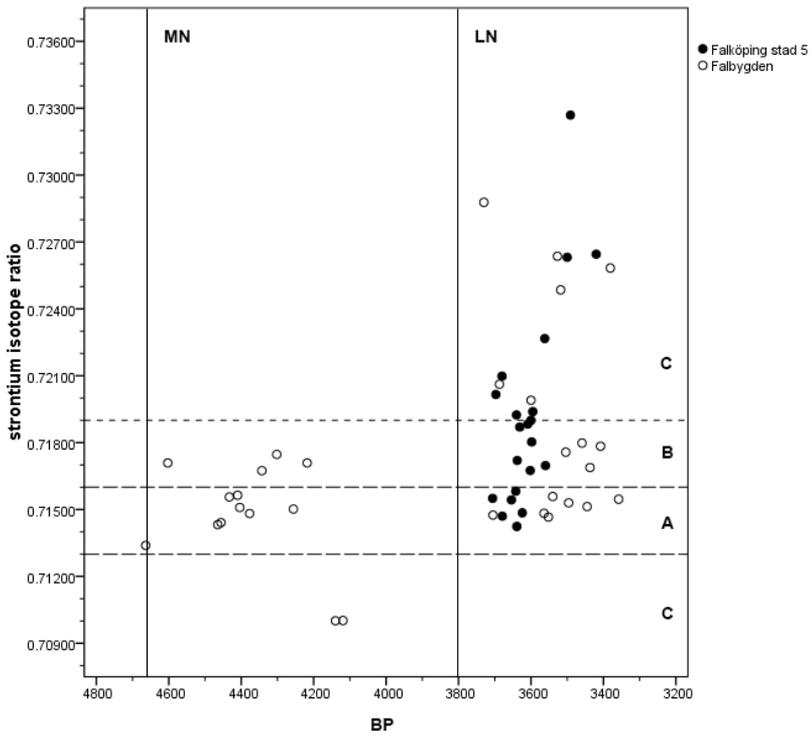
are rare in these parts (Blank & Knipper, in press; Sjögren et al., 2009). Ratios between 0.726 and 0.733 have been observed in the eastern parts of south-central Sweden (Åberg & Wickman, 1987, p. 36f; Eriksson et al., 2016; Lindström, 2009; Price et al., 2017).

There is a distinct increase in human mobility during the Late Neolithic in Falbygden (Blank & Knipper, in press; Sjögren et al., 2009). In the Late Neolithic, individuals with high strontium isotope ratios, not visible in the Middle Neolithic population, are present (Blank & Knipper, in press; Figure 15). Increased mobility, contacts, and interactions between Late Neolithic groups on the island of Öland, southeast Sweden, have also been claimed based on carbon and nitrogen, as well as sulphur isotopes (Linderholm et al., 2014). The increased human mobility could be explained by intensified trade, connected to new artefacts such as flint daggers and new raw materials such as bronze and gold. Long distance networks with Corded Ware and Bell Beaker groups, as well as with the Únětice culture of central Europe, can be observed in the southern Scandinavian Late Neolithic archaeological record (Apel, 2001; Artursson, 2009; Vandkilde, 1996). These cultural influences are also visible in Falbygden (Apel, 2001; Weiler, 1994), and even if the strontium isotope results cannot confirm long distance migration, the higher degree of mobility perhaps indicates increased trade with the surrounding areas which was likely to be connected to long trade networks. The high mobility observed in individuals buried in megalithic graves might indicate that they were a part of the population which was more mobile than others. Falköping stad 5 gallery grave contains a small number of artefacts commonly found throughout southern Scandinavia. Flint does not occur naturally in Falbygden, and the flint found in the grave originates from Scania or Denmark. The dagger is most likely an import from the eastern Danish islands or south-western parts of Scania (Apel, 2001). However, the dagger could also have been produced locally, possibly from a polished flint axe as several flint flakes were found with the dagger. They are of the same raw material and have identical polishing traces (vertical) and patina (Figure 16). The dagger was manufactured by a highly skilled craftsman, and it has been argued that this kind of knowhow could only have been obtained in areas with a lot of flint (Apel, 2001, 2015). It can also be the remaining belongings of a specialised flint knapper from Scania or Denmark (see Apel, 2015). While there is no evidence of any individual with strontium isotope ratios matching the bio-available signals in Denmark or south-western Scania (see Frei & Frei, 2011 for these ratios), the flint craftsmen working in these regions were not necessarily of local origin. Even though no individuals from southern Scania or Denmark can be traced with strontium isotopes in the Late Neolithic, established contacts with this area are known to have existed in the previous Neolithic periods (Sjögren, 2003). In figure 15, two individuals dated to the previous Battle Axe Culture show strontium isotope ratios of 0.710, indicating that these individuals might have spent their childhood in southern Scania, Denmark or other regions with similar geology or affected by sea spray. The buried individuals in Falköping stad 5 have also been sampled for aDNA in an ongoing research project (The Rise). The results will provide even more information about the buried individuals and the Late Neolithic population.

## 6 Conclusion

This article presents new knowledge about the Late Neolithic megalithic population in Falbygden from an interdisciplinary perspective combining archaeology, osteology, and isotope analyses. Most gallery graves in Southern Scandinavia, including Falbygden, were in use during the Late Neolithic II and Early Bronze Age. In contrast, Falköping stad 5 had already been constructed in the Late Neolithic I. The gallery grave was most probably used for successive burials in a rather short time span of about 150 years, but two different burial phases, with the majority in the Late Neolithic I and later inhumations of three individuals in Late Neolithic II, might also be possible. Considering evidence pointing to high population density and inhumations during a short time frame, it is difficult to conclude if the burial site was used by a single family or by a larger social group. Both are considered possible, even though the high number of non-local  $^{87}\text{Sr}/^{86}\text{Sr}$  signals might favour the latter.

The demographic analyses indicate a relatively high population density and a possible population increase over time. Stature is similar to Late Neolithic populations in southern Sweden in general. Childhood



**Figure 15.** Scatterplot of strontium isotope ratios of individuals buried in megalithic graves in Falbygden, based on results from the current study and Blank and Knipper (in press). A: Local  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios, B: non-local/mixed  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios, C: non-local  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios, see text above. Lines mark periods: MN: Middle Neolithic and LN: Late Neolithic.



**Figure 16.** Flint dagger and flint flakes from Falköping stad 5. Photo by Malou Blank, CC BY.

mortality was around 30% and the risk of dying during childbearing years was high for females, while many males lived into their seventies. This mortality profile might indicate a population at high risk for infectious disease due to high population density and close contact with animals. The high mortality among children might also be related to a relatively high frequency of enamel hypoplasia caused by nutritional stress or bad health around the age of 3–4. Most individuals displaying enamel hypoplasia lived into adulthood.

The isotope values from the buried individuals in Falköping stad 5 indicate a terrestrial diet with a rather high intake of plant foods. Subsistence based on plant cultivation and animal husbandry with elements of hunting and fishing can be expected. Consumption of dairy products has been observed in a number of individuals (all of those sampled) (Fotakis et al, in preparation), probably indicating a heavier reliance on cattle, which could also in turn explain the decreased  $\delta^{15}\text{N}$  values in the Late Neolithic. It is possible that the lack of cribra orbitalia in Falköping stad 5 is connected to milk consumption and a higher availability of vitamin D. Inclusion of fish in the diet would also provide high intake of vitamin D; however, evidence of a high fish contribution to the diet is not present in the stable isotope values observed here. Some of the strontium isotope ratios might be a result of repeated movements in and out of the Falbygden area, possibly related to herding. However, this has to be confirmed by multiple analyses of teeth from the same individuals. The variation of  $\delta^{15}\text{N}$  values in Falköping stad 5 is greater than during the Middle Neolithic, which is also observed in other Late Neolithic samples from the area. The variation in stable isotope values could reflect specialisation and variation in subsistence strategies, but could also depend on social stratification and increased mobility.

The majority (71%) of the buried individuals in Falköping stad 5 have a non-local strontium isotope signal. The specimens with non-local signals associated with the first burial phase probably spent part of their childhood in the outskirts of Falbygden or in the surrounding Precambrian area. The three individuals with the youngest  $^{14}\text{C}$  dates have substantially higher strontium isotope ratios and are likely to have spent their childhood years in eastern or more northern parts of Sweden. These strontium isotope ratios are consistent with previous studies where it has been shown that human mobility increased during the Late Neolithic. These results point to increasing population dynamics throughout the Late Neolithic.

**Acknowledgements:** We thank Gerlinde Borngässer, Melanie Gottschalk, Bernd Höppner, Sigrid Klaus, and Sandra Kraus for their contributions to strontium isotope analysis at the Curt-Engelhorn-Center for Archaeometry, gGmbH, Mannheim, Germany and Michael Maus for apatite carbon isotope analysis at the Institute of Geosciences, Applied and Analytical Palaeontology at the University of Mainz, Germany. We are grateful to Karl-Göran Sjögren, University of Gothenburg, Torbjörn Ahlström, University of Lund, for comments and help with improvements on the manuscript. We also would like to thank Anna Fotakis, Natural History Museum of Denmark, for sharing results not yet published. The isotope analyses were funded by Berit Wallenberg stiftelse and The Rise project, University of Gothenburg supported by ERC.

## Abbreviations

ATA= Antikvarisk-Topografiska Arkivet, Stockholm, Sweden.

BAR= British Archaeological Reports

VG= Västergötland

SHM= Statens Historiska Museum

SLM= Skaraborgsläns museum

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## Appendix

Find No.	Context	Sample	$^{87}\text{Sr}/^{86}\text{Sr}$ Lab. No.	$^{87}\text{Sr}/^{86}\text{Sr}$ Ratio	Analytical error $\pm 2$ SD Enamel (VPDB) ‰	$^{14}\text{C}$ Lab. no.	BP	C:N	Cal BC OxCal 4.3, 95.4%	$\delta^{15}\text{N}$ Collagen (AIR) ‰	$\delta^{13}\text{C}$ Collagen (VPDB) ‰	Collagen apatite spacing	Sex	Age
F83III:1	layer 1, northern part of chamber	M2, mandibula, sin	MA-1556000.72645	0.00001	-14.28	UBA-30770	3420 $\pm$ 33	3.18	1874-1630	10.6	-20.9	6.6	Male?	30+
F139II:2	layer 2, northern part of chamber	M2, mandibula, dexter	MA-1556110.71803	0.00002	-14.89	UBA-30764	3598 $\pm$ 31	3.18	2031-1886	9.1	-21.1	6.2	Male	25-35
F90	upper part, northern part of chamber	dpm2, mandibula, dexter	MA-1556120.72631	0.00001	-13.94	UBA-30758	3500 $\pm$ 31	3.24	1910-1704	10.8	-20.0	6.1	Indet.	3-4
F115VII:2	layer 2, southern part of chamber	M2, mandibula, dexter	MA-1556090.71543	0.00002	-13.96	UBA-30763	3654 $\pm$ 34	3.16	2137-1940	8.9	-20.6	6.6	Male	15-20
F132VI:3	layer 3, southern part of chamber	M2, mandibula, sin	MA-1556020.71424	0.00001	-13.57	UBA-30737	3639 $\pm$ 35	3.22	2134-1911	8.9	-20.7	7.1	Male	25-35
F117	layer 4, northern part of chamber	M2, mandibula, dexter	MA-1556010.71470	0.00002	-14.81	UBA-30766	3679 $\pm$ 32	3.16	2190-1961	9.1	-20.5	5.7	Female?	Ca. 20
F108IV:3	layer 3, northern part of chamber	M2, mandibula, dexter	MA-1556160.72267	0.00002	-14.40	UBA-30767	3562 $\pm$ 49	3.15	2030-1756	10.7	-21.0	6.6	Male?	45-55
F98	layer 2, northern part of chamber	dpm2, mandibula, dexter	MA-1556060.71924	0.00003	-14.83	UBA-30774	3640 $\pm$ 33	3.22	2134-1916	9.9	-20.8	6.0	Indet.	3
F147VI:4	layer 4, southern part of chamber	M2, mandibula, dexter	MA-1555990.71485	0.00001	-14.26	UBA-30745	3624 $\pm$ 31	3.21	2121-1896	8.4	-20.6	6.3	Male	20-30
F123	unknown	M2, mandibula, dexter	MA-1556100.73269	0.00002	-14.71	UBA-30768	3491 $\pm$ 33	3.15	1902-1697	8.5	-21.1	6.4	Female?	>40
F122	layer 4, southern part of chamber	M2, mandibula, dexter	MA-1556050.71675	0.00003	-11.70	UBA-30765	3602 $\pm$ 33	3.17	2112-1883	8.3	-20.8	9.1	Male?	40-50

Find No.	Context	Sample	<sup>87</sup> Sr/ <sup>86</sup> Sr Lab. No.	<sup>87</sup> Sr/ <sup>86</sup> Sr Ratio	Analytical error ± 2 SD Enamel (VPDB) ‰	<sup>14</sup> C Lab. no.	BP	C:N	Cal BC OxCal 4.3, 95.4%	δ <sup>15</sup> N (AIR) ‰	δ <sup>13</sup> C Colla- gen (VPDB) ‰	Colla- gen (VPDB) apatite spacing	Sex	Age
F119	layer 3, northern part of chamber	dpm2, mandibula, dexter	MA-1556130.71720	0.00003	-15.10	UBA-30771	3638±35	3.21	2134-1910	10.4	-20.4	5.3	Indet.	Ca. 6
F121	layer 3, southern part of chamber	M2, mandibula, dexter	MA-1556040.71939	0.00002	-14.36	UBA-30749	3595±33	3.17	2110-1880	9.3	-20.8	6.4	Female	35+
F134	layer 3, southern part of chamber	M1, mandibula, sin	MA-1556150.71870	0.00004	-15.40	UBA-30735	3631±42	3.23	2135-1891	9.3	-20.4	5.0	Indet.	12- 20
F69	upper part, southern part of chamber	M2, mandibula, dexter	MA-1556070.71582	0.00002	-14.44	UBA-30742	3642±32	3.18	2134-1921	9.1	-20.5	6.1	Male	20-30
F124	layer 3, northern part of chamber	M2, mandibula, dexter	MA-1556080.71900	0.00002	-15.45	UBA-30775	3600±33	3.21	2112-1882	9.9	-21.4	6.0	Male	45+
F118	layer 3, northern part of chamber	M1, mandibula, dexter	MA-1556190.71697	0.00003	-14.83	UBA-30769	3560±33	3.15	2018-1774	8.6	-21.0	6.2	Male	13-15
F88	ante chamber	dpm2, mandibula, dexter	MA-1556140.71883	0.00001	-15.59	UBA-30753	3609±41	3.22	2132-1880	10.5	-21.4	5.8	Indet.	4-5
F129V2:2	layer 2, under roof slab western part	M1, mandibula, dexter	MA-1556030.72016	0.00001	-15.70	UBA-30762	3697±37	3.20	2201-1975	9.5	-21.1	5.4	Male?	>40
F128	layer 3, northern part of chamber	M3, mandibula, dexter	MA-1556180.72098	0.00002	-16.06	UBA-30773	3680±33	3.19	2192-1960	9.9	-21.6	5.5	Female	adult
F120+132	layer 3, southern part of chamber	M1, mandibula, dexter	MA-1556170.7155	0.00001	-14.03	UBA-30772	3706±36	3.21	2202-1980	10.8	-20.5	6.5	Female?	40+



Paper IV





# The paleodemography of Late Neolithic–Early Bronze Age agro-pastoralists from southern Sweden

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## Abstract

The general assumption has long been that prehistoric people died young and that the low number of children present in skeletal assemblages is a result of taphonomic loss. In this paper I have used transition analysis for age estimations and modelled demography using a Siler competing hazard model in a pooled LN–EBA skeletal sample from southern Sweden. The results show that individuals with high ages are, in fact, present in prehistoric skeletal assemblages and that the earlier assumptions are biased by methodological problems. I also conclude that low rates of child mortality in LN–EBA Sweden is dependent on relatively low population density that decreases the risk of dying from infectious disease as a child and is not a reflection of high taphonomic loss. The high rate of mortality among young adults is further suggested to be caused by an elevated risk of dying from conflict-related injuries.

Keywords: Paleodemography; Siler Competing Hazard Model; Late Neolithic; Early Bronze Age; Transition Analysis; Sweden

## Introduction

Between 1751 and 1800, 84.3 out of 1000 infants under the age of four in Sweden would die under the age of four. In the first half of the 1900s, this number was 17.74. Mortality rates, then, remained relatively low until deaths related to senescence increased death rates in the later part of life. In the 1751–1800 samples, age-related mortality starts increasing in the mid-60s. Increased rates of age-related mortality in the first half of the 1900s is not visible until a decade later (Statistics Sweden). Average life expectancy has increased by almost three months annually over the past 160 years (Gurven and Kaplan, 2007) and has been connected to medical development and better hygiene. Gurven and Kaplan, based on Hawkes et al. (1998) and Pecchio (2001), propose a modal age of seven decades of life for humans. They argue that surviving for so long past reproductive age depends on the “grandmother hypothesis” or the “mother hypothesis”. According to this theory, post-menopausal women could increase the survivorship for their grandoffspring or the fertility of their offspring through help with provisioning, and thereby be of essential importance in an evolutionary sense (Gurven and Kaplan, 2007).

Although life expectancy has increased dramatically during the last decade, the decrease in the mortality rate is mostly associated with the youngest and the oldest in a population, while there are very small changes within the population with the lowest risk of dying (Burger et al., 2012). The shape of the mortality curves therefore differ inconsiderably while the actual values differ extensively (Burger et al., 2007). Somewhat provocatively, Burger et al. (2012) concludes that there are larger differences in mortality between populations living in countries with the highest life expectancies and contemporary hunter-gatherers than between contemporary hunter-gatherers and chimpanzees. Ahlström, however, argues that demography of contemporary populations cannot be automatically transferred to past populations (Ahlström, 2015). In his study of prehistoric south Scandinavian hunter-gatherers, he concludes that prehistoric hunter-gatherers display lower rates of child mortality, and higher mortality that does not correspond to child or senescent mortality, than contemporary hunter-gatherers. Low child-mortality rates in past populations are often referred to as the result of taphonomic loss (Lewis, 2007). Brothwell (1987) argues for infant mortality

rates (<1 years) equally high, or higher, than mortality rates within the 1-5 year-old age-span. Infection is the primary reason for child mortality in the world today (Roberts and Manchester 2005; Black et al., 2008) and is strongly correlated with both sanitation and population density. Ahlström (2015) argues that low numbers of children in prehistoric skeletal assemblages are, in fact, reflective of actual low rates of child mortality due to low population density and thereby a low risk of dying from infection. Accordingly, the low numbers of children in these assemblages should not be explained only as the result of taphonomic loss.

In their almost dystopic article, Bocquet-Appel and Masset (1982) highlight the methodological problem of most age-estimation models within bioarchaeology. The estimated ages at death of the individuals in an archaeological cemetery, and the mortality patterns, did not correlate with the reported ones in historical sources. They said farewell to paleodemography until new methods could solve this problem. Years of testing against known-age skeletal samples and development of new age-assessment methods followed (Lovejoy et al., 1985; Brooks and Suchey, 1990; Meindl and Russell, 1998).

In 2000, scholars interested in paleodemography met up for a workshop in Rostock trying to solve the methodological problems of paleodemography. They authored a Rostock manifesto (Hoppa 2002; Hoppa and Vaupel 2002) which outlines four major concerns that should be met in paleodemographic research: i.) development of more reliable and validated age indicator stages from reference populations; ii.) to (from the above data) develop models to estimate  $\Pr(c|a)$ , which correspond to the probability ( $\Pr$ ) of observing specific skeletal characteristic ( $c$ ) at a given age ( $a$ ); iii.) recognition that what is of paleodemographic interest is  $\Pr(a|c)$ , equalling the probability that skeletal remains are from an individual at age ( $a$ ) considering the morphological features ( $c$ ). This association could only be assessed through calculations of  $\Pr(c|a)$  using Bayesian statistics and information about  $f(a)$ , which is the probability distribution of age at death in the population; and iv.)  $f(a)$  must be estimated before  $\Pr(a|c)$  could be assessed (Hoppa and Vaupel, 2002). These concerns have largely been met in the methodology of transition analysis (Baldsen et al., 2002). Earlier methods of ageing individuals had problems with assessing ages over 50, making the highest age-at-death present in the material appear to be younger than it probably was. However, the use of transition analysis would also make it possible to

age individuals over 50 years more precisely if they were in fact present in the material.

Wood et al. (2002) acknowledge that it is impossible to examine demography in ancient populations in such detail as is possible for demographers working with contemporary populations due to the many unavoidable difficulties within paleodemography, such as, for example, retrieving large skeletal populations, the actions of taphonomic agents, unknown ages and sexes, and, most often, unknown causes of death. Despite these restrictions, paleodemography analyses are of great value for understanding mortality patterns and societies in the past. In this paper, I present the results of a paleodemographic study of the LN–EBA population in southern Sweden. The LN–EBA in southern Sweden is characterized by deforestation and intensification in agro-pastoral subsistence (Digerfeldt, 1975; Berglund, 2003; Engelmark and Linderholm, 2008) that eventually led to a fully developed Bronze Age society with long-distance trade contacts and pronounced mobility (Vandkilde, 1996; Harding, 2013; Earle et al., 2015; Kristiansen and Earle, 2015; Bergerbrant et al., 2017). This development is also connected to an assumed population increase (Apel, 2001, 2004). There have also been several reports of Neolithic and Bronze Age violence based on skeletal remains from northern Europe ( Fyllingen, 2003; Fibiger et al., 2013; Jantzen et al., 2015; Tornberg and Jacobsson, 2018) and suggestion of warrior elites in both the later part of the Neolithic (Iversen, 2017) and in the Bronze Age (Harding, 1999; Kristiansen, 1999; Fyllingen, 2003; Iversen, 2017). A high rate of violence-inflicted trauma is likely to affect demography towards an increased risk of dying in mid-life whereas population increase has a correlation with many children in the material.

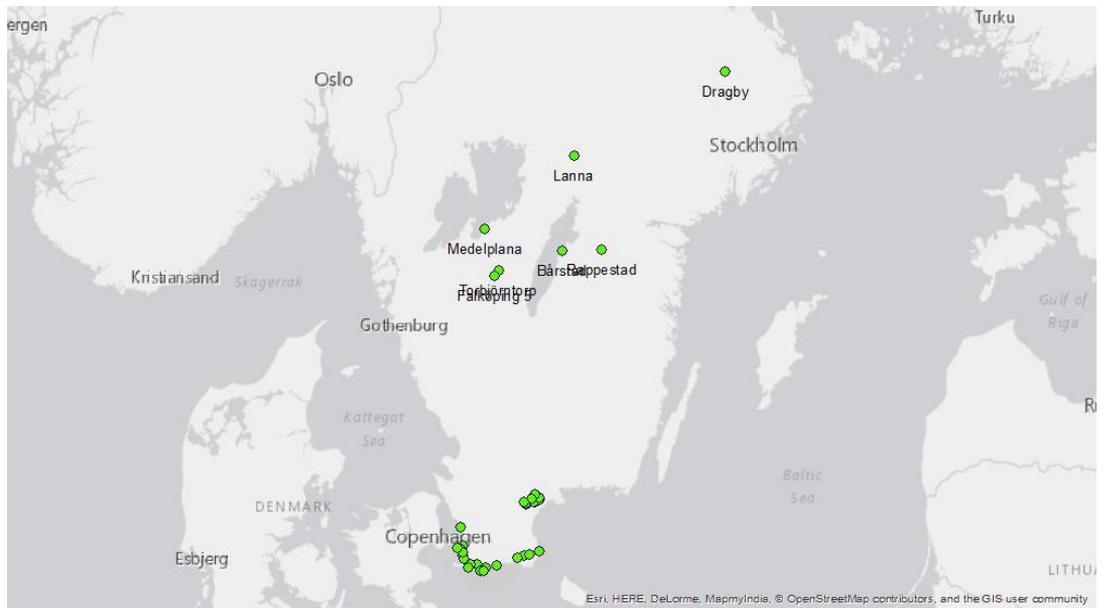
Paleodemography was analysed through a modified two-component Siler competing hazard model and was compared to mortality data from eighteenth-century Sweden and Denmark as recorded in church documentation. The documentation of data from church records encompasses parishes with high, moderate, and low population densities. Two of the parishes are situated in northern Sweden (Jokkmokk and Junsele) and two are situated in southern Sweden (Lund and Gustav Adolf). The last comparative population comes from records from the parish Sörbymagle-Kirkerup on western Sealand, Denmark. The Swedish data is extracted from the TABVERK, Center for Demographic and Ageing Research (CEDAR), which is a database with statistics about population, such as size and mortality rates,

based on parish records from the years 1749–1859 (CEDAR, Umeå University).

Has the use of transition analysis made it possible to find individuals over the age of 50 in the LN–EBA population? To what extent does the demographic model based on a skeletal population from the south Scandinavian LN–EBA correspond to the comparative populations? Which stressors might have affected the demographic profile of the south Scandinavian LN–EBA population?

## Material and Methods

The material is a pooled skeletal sample from 44 localities in southern Sweden (Figure 1) that is dated to the LN–EBA by typological features of burials and burial goods, and a large number of radiocarbon dates ( $n=86$ ). The majority of the material was excavated prior to 1960. The geology at the sites is primarily limestone, which generates well-preserved skeletal remains which, in turn, comprises both mature and immature bones (Figure 2). In total, the material comprises a minimum number of 305 individuals from the LN–EBA: 225 were adults and 80 individuals were subadults. Of these, 78 subadults and 54 adults could be aged more specifically (Table I). Since the proportion of subadults that could be assessed with age (97.5%) is much higher than the proportion of adults (24.0%) (dependent on the lack of intact pubic bones and auricular facets), the number of individuals in each age class has been adjusted so that the total number in the sample fits the total number of individuals. The subadults and adults that could not be assessed with a specific age were divided proportionally based on % between the age-classes for the adult and subadult population respectively. This strategy might enhance the difference between the largest and smallest age-groups but to divide the sample evenly would reduce the variability already seen in the sample and would not be in coherence with Bayesian statistics. If the sample had have been left completely unmodified it would bias the demographic profile towards a higher relative proportion of child deaths than is actually present in the sample.



**Figure 1.**

Map of southern Sweden with burials included in this paper marked in green. The majority of the material derives from Scania in southernmost Sweden and is not marked with site names for readability. The Scanian samples include inhumations in gallery graves, flat earth graves, and mounds/cairns. The samples from the provinces of Västergötland, Östergötland, Närke, and Uppland are all gallery graves with multiple inhumations. Map constructed with ArcGIS 10.5 by Esri.

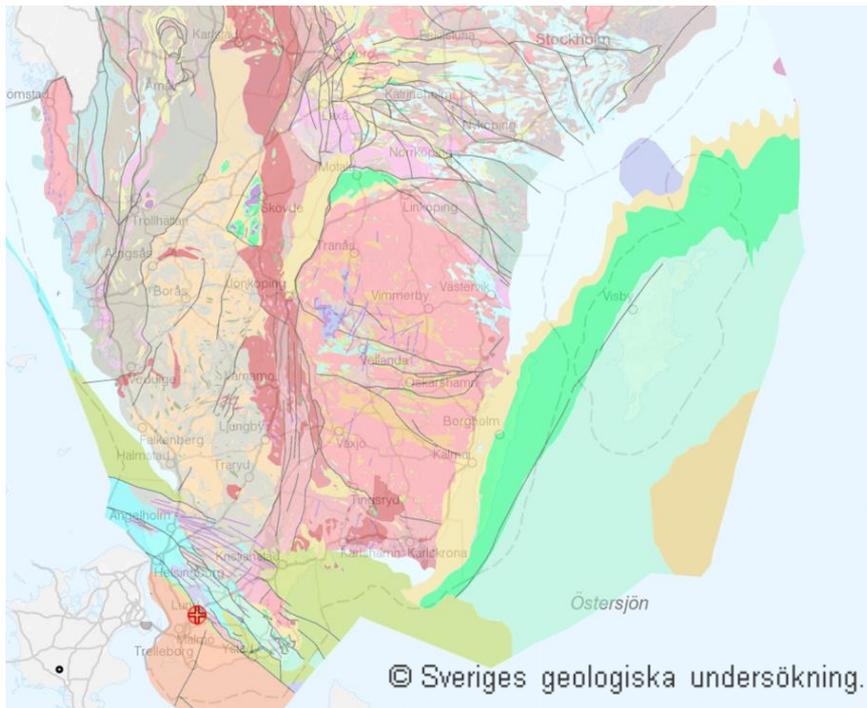
**Table 1.**

The number of individuals in each age class. Values are modified to sum up to the total number of subadults (n=80) and adults (n=225) respectively. The added number of individuals is distributed proportionally (%) across the sample. The corrected values are used in the demographic model.

Age	#	Corrected
0-1	7	7
1-5	17	17
5-10	23	24
10-15	21	22
15-20	12	12
20-30	11	51
30-40	5	21
40-50	4	17
50-60	2	8
60-70	2	9
70-80	25	106
80-	3	13

In accordance with the Rostock manifesto, adult age has been estimated using transition analysis as recommended by Milner and Boldsen (Boldsen et al., 2002; Milner and Boldsen, 2012). Features of the pelvis and skull have been recorded in the ADBOU database for transition analysis and were analysed with a 95% confidence interval using an informative archaeological prior with unknown ancestry. The archaeological prior is based on a seventeenth-century rural skeletal sample from Denmark (Boldsen et al., 2002). It is, of course, problematic to presume that LN–EBA demography is equal to that of the seventeenth-century, and this difference might generate bias in the age estimates. However, using the uninformed prior would reduce the benefits of the transition analysis and generate age estimates that we do know to be biased by age-mimicry. Boldsen et al. (2002) also articulate that the use of an informative prior is possible also for populations with unknown age distribution when related to general demographic models, such as the Siler model. The point estimate ages from the transition analysis have then been used for demographic modelling. It should be noted, however, that in most cases only one area could be used for analysis, most often the auricular surface, which has resulted in fairly long age intervals (available as supplementary material). In a few cases, the transition analysis point value

gives a lower age than is possible due to bone maturation. This occurs when the auricular or pubic surface has a very youthful appearance but growth is completed, indicated by complete skeletal fusion. In these cases, age has been adjusted to the nearest age where bone maturation is completed. All of these cases still fall well within the 95% confidence interval. Juvenile age has been recorded using traditional osteological methods of tooth formation, bone maturation, and osteometry (Buikstra et al., 1994; Schaefer et al., 2009).



**Figure 2.** A geological map of southern Sweden. Limestone bedrock (orange and green colour) is present in the majority of the sites included in this paper, providing generally good preservation of bone. Source: Geological Survey of Sweden, SGU.

Demography was analysed using a modified two-component Siler competing hazard model (Siler, 1979; 1983; Wood et al., 2002). The model is based on two components of human mortality. The first (immature) component refers to the high but decreasing infant and young-child-mortality rates and the third (senescent) component is related to the increased risk of dying with increased age. The traditional second, age-independent (residual,  $\alpha_2$ ), component has been excluded since that baseline is generally established where the first and

second component meets. The modified Siler model has four parameters that comprise the population mortality.  $\alpha_1$ =immature mortality rate,  $\beta_1$ =the rate of immature mortality decline,  $\alpha_3$ =the initial adult-mortality rate, and  $\beta_3$ =the rate of adult mortality increase. The Siler analysis was made in the free statistical software R, version 3.1.3 (R Core Team, 2015) using a code modified from Frankenberg & Konigsberg (2016). It should be noted that Wood et al. (2002, p. 149f) discuss the problem with the immature component of the Siler model for both modern and archaeological samples and suggest large sample sizes and narrow age ranges for the first five years. In this study, the sample only comprises 24 children under the age of five, which could, of course, affect the outcome of the analysis. However, since there is a connection between population increase, population density, and demography, it was considered of scientific value to also estimate the subadult mortality pattern, especially since there is little knowledge about child mortality and demography of LN–EBA agro-pastoralists in general.

## Results

The results from the transition analysis show that the most common age at death in the adult population is between 70–80 years. The results of the Siler analysis are presented in Table II and Figure 3. The parameters from the Siler model are presented in Table II. Figure 3 depicts survivorship of the different population at different ages. The LN–EBA population of south Sweden shows a low rate of infant mortality with a high attrition throughout the lifespan. A relatively large part of the population survived into their seventies, however. After that, the survival declines more rapidly. A high attrition throughout the lifespan is connected to high risk of dying as a young adult. This is often related to increased risks of dying from pregnancy or childbirth, as well as violence and accidents (Wood et al., 2002, p. 149). In the case of the LN–EBA, most of the mortality not connected to child or senescent mortality is connected to adolescents and young adults.

The populations from eighteenth-century Sweden and Denmark display completely different survivorship curves. All of these populations exhibit significantly higher rates of child mortality than the LN–EBA sample. However, there are variations between the eighteenth-century populations as well. The population of the sparsely populated Junsele parish in northern Sweden (238 individuals in 1758) appears to have a much lower rate of child mortality than the others. The difference is clearly distinguishable in the first year up to five years of age. In the data documented in church

records from Junsele parish, only 10% of children died within their first year and around 20% before reaching five years of age. The same ages in Jokkmokk parish (northern Sweden) show child-mortality levels of 40% and 50% respectively. The central town parish of Lund (southern Sweden) has a child-mortality rate of approximately 30% within the first year and 50% within five years. These two populations show the highest rates of child mortality in the comparative materials. They also have the largest living populations, with 1128 individuals in Jokkmokk parish and 2750 individuals in Lund, St Laurentii parish in 1749 (CEDAR, Umeå University). The Gustav Adolf parish (southern Sweden) and Sörbymagle-Kirkerup have child-mortality rates that can be considered intermediate. The population size of Gustav Adolf parish is low, with 293 individuals in 1749 (CEDAR, Umeå University), but it is situated geographically close to the region's capital, Kristianstad. The population size of Sörbymagle-Kirkerup is unfortunately unknown. When comparing the two Sörbymagle-Kirkerup samples it is evident that the child-mortality rate is elevated when individuals dying from plague are included in the Siler analysis. This shows the higher frailty and the higher risk of death due to infection among small children.

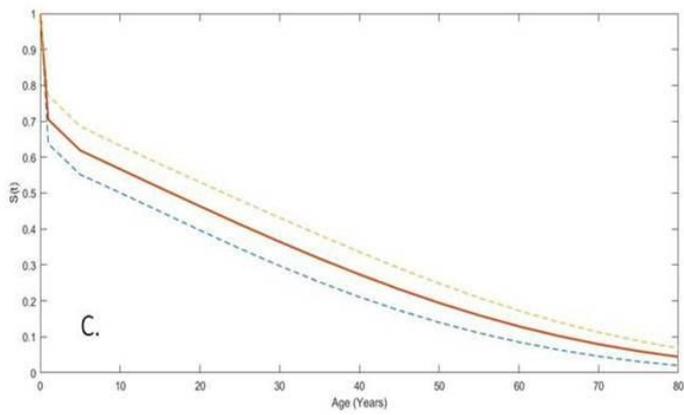
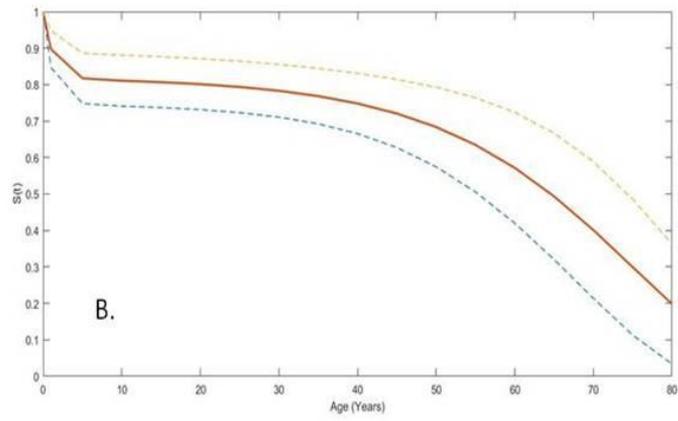
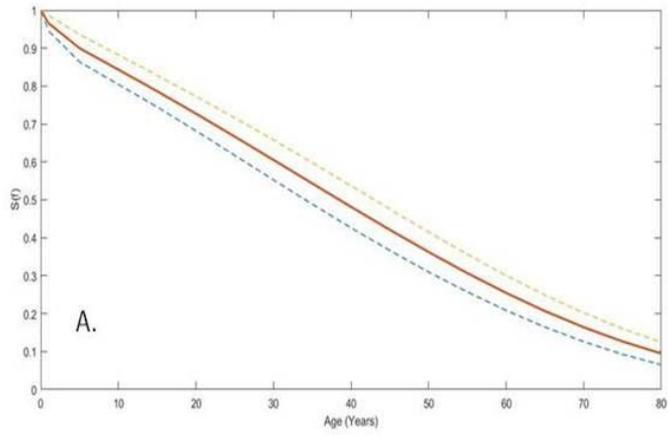
**Table II.**

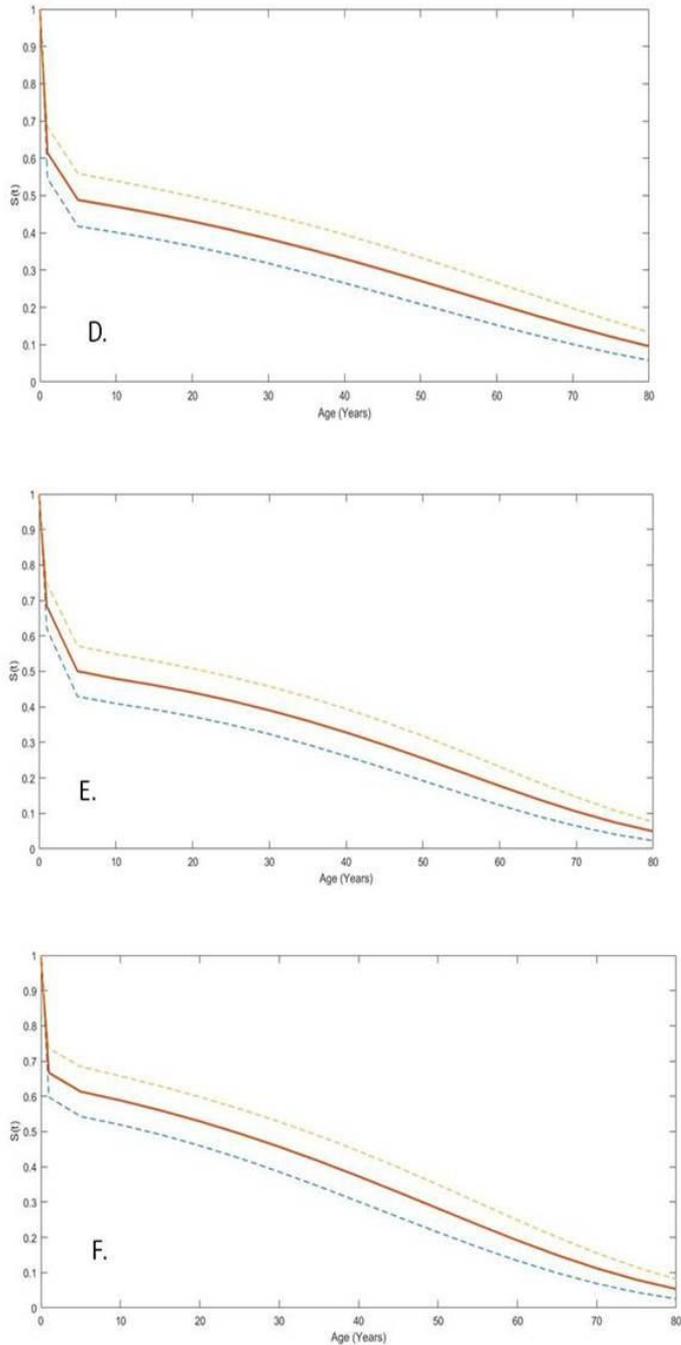
Siler models with parameters from LN–EBA southern Sweden (n=305), Junsele parish 1751–1760 (n=32), Gustav Adolf parish 1749–1758 (n=96), Jokkmokk parish 1750–1759 (n=356), Lund St Laurentii parish 1749–1758 (n=793) and Sörbymagle-Kirkerup (n=489). All samples are based on data comprising both sexes. All samples are Swedish except for Sörbymagle-Kirkerup that is a Danish parish. Swedish data comes from TABVERK, Center for Demographic and Ageing Research (CEDAR), Umeå University. Data for Sörbymagle-Kirkerup is gained from (Højrup, 1969)

Population	$\alpha_1$	Variance	$\beta_1$	Variance	$\alpha_3$	Variance	$\beta_3$	Variance
<b>LN-EBA</b>	0.030418 661	0.01 70	1.05587 1899	0.36 64	0.00830 8253	0.00 15	0.02505 6424	0.00 26
<b>Junsele</b>	0.153984 3029	0.04 83	0.75463 46274	0.17 83	0.00040 69303	0.00 02	0.06843 18208	0.00 38
<b>Gustav Adolf</b>	0.726169 76	0.13 70	1.81896 219	0.23 80	0.01539 671	0.00 26	0.01772 918	0.00 33
<b>Jokkmokk</b>	0.828494 823	0.12 11	1.20556 7730	0.13 09	0.00583 2335	0.00 14	0.02700 9744	0.00 35
<b>Lund</b>	0.545214 98	0.08 11	0.80442 011	0.09 13	0.00480 696	0.00 13	0.03666 594	0.00 43
<b>Sörbymagle-Kirkerup</b>	0.959285 812	0.16 58	2.11616 0547	0.26 40	0.00650 5961	0.00 14	0.03235 6534	0.00 35

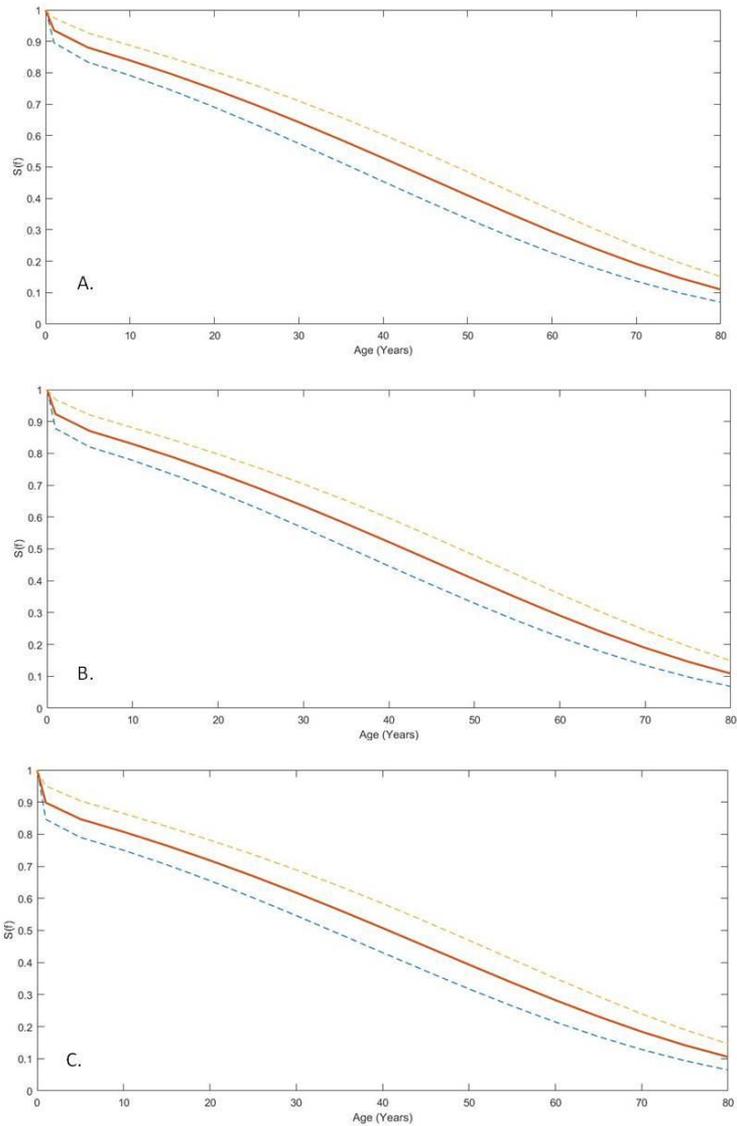
Although there are tendencies to believe that rates of child mortality in the eighteenth century are lower in parishes which have smaller populations than in more densely populated parishes, the Siler model displays much lower child-mortality rates in the LN–EBA sample than in either of the eighteenth-century populations. Since it is possible that some of the youngest, smallest and most fragmented skeletal remains have been lost additional Siler models were created to visualize how the mortality curves would look like if infant mortality (<1 years) would have been 25, 50, and 100% higher than the mortality among 1-5 years old (Figure 4). It is evident that, although infant mortality rates are significantly elevated, child mortality rates are still very low.

Unfortunately, there are no LN–EBA skeletal samples that have been aged through transition analysis which could have functioned as comparative material. The possible comparative samples analysed by Angel (1969) were excluded since the aging methodology used in his analysis is insufficient to assess the oldest ages. Older aging methodologies such as those used by Lovejoy et al. (1985), Buckberry and Chamberlain (2002), and Brooks and Suchey (1990) are also regarded as too biased by age mimicry to function as comparisons. However, to further evaluate whether there are different child-mortality rates between densely and less densely populated areas in prehistoric times, a very rough age estimate was made for some of the populations analysed by Angel (1969) (Table III). If the population was to be divided only between subadult (skeletally and dentally immature) and adult (skeletally and dentally mature) individuals, the samples would not be biased by differences in ageing methodology and could thus be compared. When doing so, it is evident that there is a strong resemblance between the LN–EBA sample from southern Sweden and the EBA population of Karataş in Anatolia, while the other populations have a markedly higher proportion of subadults.





**Figure 3.** Survivorship curves of (A.) LN-EBA southern Sweden; (B.) Junsele parish; (C.) Gustav Adolf parish; (D.) Jokkmokk parish; (E.) Lund, St Laurentii parish; and (F.) Sörbymagle-Kirkerup. Y-axel showing survival funktion and X-axel showing ages in years.



**Figure 4.** LN-EBA survival modelled with infant (< 1 year) mortality is 25 – 50 – 100% higher than child mortality rate in the age-class 1-5 years. A= 25%, B= 50%, C= 100%.

**Table III.**

The proportion of subadult and adult deaths in the skeletal populations of LN-EBA in southern Sweden, EBA Karataş in Anatolia, BA Lerna in Greece, Classic Athens and Neolithic Çatal Höyük.

Sample	No. subadults (<20 y)	No. adults	Total no. individuals	% subadults	% adults	Reference
<b>LN-EBA southern Sweden</b>	80	225	305	26.23	73.77	Tornberg, this study
<b>EBA Karataş</b>	81	231	312	26	74	Angel, 1969
<b>BA Lerna</b>	140	94	234	59.8	40.2	Angel, 1969
<b>Classic Athens, 650-350 BC</b>	70	74	144	48.6	51.4	Angel, 1969
<b>Catal Höyük, 6500-5300 BC</b>	226	206	432	52.3	47.8	Angel, 1969

Lerna, Athens, and Çatal Höyük are all characterized as being types of proto-city or early urban settlements, and thus as having a markedly higher population density than in LN–EBA southern Sweden where the first hamlet-size settlements occurred (Artursson, 2009; Brink, 2013). The cemetery of EBA Karataş is large (Massa, 2014; Fidan et al., 2015) and thoroughly excavated, although with some sex bias in the material (Angel, 1969). The site is, however, referred to as a village and is not likely to have been as densely populated as Lerna, Athens, and Çatal Höyük were. Considering the geological preconditions in southwestern and southernmost Sweden, it is unlikely that this material has suffered from greater taphonomical loss than the southern European-western Asian counterpart.

## Discussion

This paper provides evidence that demonstrates that it is unreasonable to believe that all prehistoric individuals lived short lives and died before the age of 50. In fact, this paper provides evidence showing that as much as 39% of all deaths (n=305) might actually have occurred in the eighth or ninth decade of an individual's life. Gurven and Kaplan (2007) conclude that *Homo sapiens* have a modal lifespan of seven decades. The results of the Siler model also show that mortality increases more rapidly after the age of 70, which is consistent with the modal age of Gurven and Kaplan. These pieces of evidence show that the general view that prehistoric humans rarely lived past the age of 40 is false, and that these assumptions are based on age-at-death estimations of poor methodological accuracy and problems with assessing ages over 50 (Boldsen et al., 2002). This assumption is further questioned by the fact that data from church records also show similar patterns of survival to old ages. By using transition analysis as recommended by Boldsen et al. (2002), problems relating to age-mimicry and all old individuals being categorized as 'age 50+' are neutralized. The results clearly show that a large proportion of the individuals during the LN–EBA lived well into their seventies. The highest rate of mortality in south Swedish LN–EBA is actually found between the ages of 70 and 80, which is consistent with twentieth-century Sweden.

There are, however, two distinct features of LN–EBA mortality that differ significantly from the comparative populations according to church records, namely, a low child-mortality rate and a high young-middle adult mortality.

Since there are clear differences in relative subadult deaths between the archaeological populations in this paper, it is not possible to speak of a general LN or Bronze Age mortality. Neither is it reasonable to believe that the large differences in the relative proportions of subadult and adult deaths are caused by differences in taphonomic loss of subadult skeletal remains, especially since the geology of southernmost and southwestern Sweden is suitable for good preservation of bone. Low numbers of children in archaeological skeletal assemblages are often explained as the result of taphonomic loss, as immature bone chemically has a higher organic

proportion than mature bone, which makes it more susceptible to taphonomic agents. Archaeological samples of older date should, in this case, generally suffer from more taphonomic loss than more recent skeletal assemblages. Ahlström (2015) argues that this is not the case. Considering that the oldest skeletal assemblage in this study, namely that of Çatal Höyük, also has one of the largest relative amounts of subadult deaths, Ahlström's proposal seems correct. Based on demographic analyses of Swedish prehistoric foragers, he concludes that low child-mortality rates in this case are dependent on a low population density (Ahlström, 2015). Child mortality is primarily caused by infectious disease (Roberts and Manchester, 2005, Black et al., 2008). Microbiomes causing infections need hosts to live and spread. A low population density provides few hosts and few opportunities to spread, in contrast to highly dense populations, such as in towns. Cockburn (1977, p. 109) argues that in a population of 5000 individuals an influenza epidemic would be completely extinct within only six months, and at very low levels already after 13 weeks. Ahlström's argumentation thus makes sense and I here argue that the differences in the proportion of child deaths are, in fact, reflecting a real difference in child mortality which is related to population density and, in turn, the risk of infectious disease which lead to child deaths within the populations. When analysing the data of Junsele parish (which was collected not through osteological analyses but through church records), the survival curve shows child-mortality rates that are only marginally higher than in the LN-EBA skeletal record. Thus, low rates of child mortality do not necessarily result from taphonomic loss.

The relation between population density and child mortality is also reflected in the Siler models, where the samples from the highest populated areas also exhibit the highest levels of child mortality. The town of Lund has been of high religious importance since the twelfth century and its university was established in 1666. Jokkmokk in northern Sweden is famous for its role as a market place with an annual market that was established in 1605. Both places were areas of new contacts and mobility which would enhance the risk of infectious disease. The small parish of Junsele in the inland of northern Sweden, on the other hand, is contemporary with the other comparative populations but provides evidence for only one-third of the child mortality. All of these populations, however, have significantly higher child-mortality rates than what is present in the LN-EBA sample. This scenario is to be expected since people in the eighteenth century were far more mobile than what can be expected from individuals living in the LN-EBA, although there is evidence of relatively frequent short- and long-distance mobility already

during the LN–EBA (Frei et al., 2015; Bergerbrant et al., 2017; Blank et al. 2018). However, close geographical and social contact with large towns or even cities in the eighteenth century far exceeds what is reasonable to consider taking place in the LN–EBA society.

Roth (1986) reports increased fertility and decreased mortality rates for African pastoralists when settling down which resulted in a rapid population growth. Sedentary lifestyles where a population increase would result in people living closer together would thus increase mortality again (Cockburn, 1977). There are strong indications that the LN–EBA society in southern Sweden primarily lived as agro-pastoralists, reflected in both the heavy undertakings of deforestation to open up for pasture lands and the zooarchaeological remains ( Digerfeldt, 1975; Berglund, 2003; Vretemark et al., 2010). Although permanent settlements are frequent in this period (e.g. Artursson, 2009; Brink, 2013), it is probable that transhumance was present, which is also somewhat supported by strontium isotopes analyses in a gallery grave at Falbygden (Blank et al., 2018). The deforestation is also considered a sign of population increase during this period. When considering the mortality profile of LN–EBA south Sweden, such a population increase is not readily visible. The low levels of child mortality rather point to a fairly low population pressure which would not cause substantial risk of infections. The increased risk of dying for older children and adolescents, however, might be reflective of this population increase. Further, as Cockburn (1977, p. 109) presents, a population of as many as 5000 individuals would not sustain infections for any substantial time. Bartlett (1960) puts the population threshold for sustaining measles until it could be re-introduced from outside (approximately two years later) to 250000–300000 individuals in a community. This population density should be considered alongside the fact that in 1750 there were only 10–15 persons/km<sup>2</sup> living in the majority of the areas from where the LN–EBA skeletal material derives (Statistics Sweden). There are also estimates of a population of 21000–43000 citizens in Attica in the fourth–fifth century BCE, excluding children, resident foreigners, and slaves. This estimate would correspond to a population density of at least 50 persons/km<sup>2</sup> (Andersson, 1991). This population density is substantially higher than in eighteenth-century southern Sweden and is a plausible explanation of the high relative child-mortality rates in classical Athens and probably also in the pre-dating Greek Lerna. It is unlikely that LN–EBA societies would encompass such large communities considering settlement sizes, even if there a population increase occurred. However, the construction of gallery graves for multiple inhumations in southern Scandinavia around

2000 BCE might be related to such an increase. It is also likely that substantial numbers of LN burials are missing because of the practice of re-using graves in the EBA, and a habit of ‘cleaning out’ the grave prior to burial. In Scania, the majority of burials in gallery graves are in fact dated to the EBA (Bergerbrant et al., 2017; Tornberg, 2017).

The second major difference between the mortality profiles of LN–EBA Sweden and the eighteenth-century populations is the mid-life mortality that decreases the population relatively even throughout the lifespan. In the comparative population there is a relatively low risk of dying in adulthood before the risk increases again in the later part of the lifespan, thus senescent mortality. In the LN–EBA sample, the mid-life mortality is elevated; there is a higher risk of dying at the age of 30 than at age 60. This mortality can depend on a number of things, but it is likely that problems in relation to childbirth and violence are strong contributors. During the late eighteenth and early nineteenth century, relatively modern methods of medicine were practiced, thus reducing the risk associated with child birth, *sensu lato* mid-life mortality. The high frequency of violence-related trauma in Neolithic and Bronze Age northern Europe (Fyllingen, 2003; Fibiger et al., 2013; Jantzen et al., 2015) is a factor that plausibly increase the risk of dying as a young adult. The high frequency of skull trauma might be connected to an assumed warrior-elite in the late part of the Neolithic and the Bronze Age (Harding, 1999; Kristiansen, 1999; Fyllingen, 2003; Iversen, 2017). However, the possibility of care was available (Tornberg and Jacobsson, 2018) which would also have been beneficial for survival for at least some time. Milner et al. (2015), on the other hand, found a correlation between ante-mortem skull trauma and early deaths which they explained as a plausible consequence of traumatic brain injury. It is therefore likely that a high number of skull traumas that caused traumatic brain injury could explain the elevated risk of dying as a young adult in LN–EBA southern Sweden.

Although all skeletal remains suffer from some taphonomic loss there is strong evidence to believe that low presence of immature skeletal remains in a prehistoric assemblage is not by necessity biased by high taphonomic loss. Instead, it might reflect actual low levels of child mortality. This view is also supported by Lewis (2007). It is clear that there is not a definite consistency to the assumption that skeletal material of an older age would comprise a lower amount of immature skeletal remains. Instead, the argumentation of Ahlström (2015) is further strengthened, since there is a close connection between population density and child mortality both in archaeological and

historical church data. Because of the early excavation date of the LN–EBA sample, it is plausible that some of the youngest individuals were not retrieved during excavation. Although some taphonomic loss plausibly is present for the skeletal remains from LN–EBA southern Sweden considering the low prevalence of children below the age of one, I argue that this loss is not as extensive as one might argue as if it was assumed that a normal infant-mortality rate was 30%. It is probable that child mortality-levels were lower than this in prehistory. Furthermore, if the death rate of children under the age of one year is of a similar proportion as between the ages of one and five, as is suggested by Brothwell (1987) (also in Lewis, 2007), child mortality would still be significantly lower than in other, more densely populated, contemporary populations. Low frequencies of immature remains might thus reflect actual low rates of child mortality dependent on low population density and, in turn, low risk of dying from infectious disease.

## Conclusions

The assumption that prehistoric individuals did not reach ages above 50 is the result of a bias caused by methodological issues. When using Bayesian statistics in age estimations, such as is the case of transition analysis, ages significantly higher than 50 can also be assessed. The majority of adult mortality in the LN–EBA of southern Sweden lies between the ages of 70 and 80. The proportion of children in the material from Lerna, classical Athens, and Çatal Höyük is markedly different from the Swedish sample and is probably reflective of early urbanism in these societies. It is much more unlikely that this had been the case in southern Sweden. The village of EBA Karataş, however, shows similar rates of child deaths as those of the southern Sweden sample. It is plausible that infections were not as common in this society due to lower population density. When comparing the Siler models, it is evident that all eighteenth-century populations exhibit higher rates of child mortality and mid-life mortality than the LN–EBA population. This is to be expected since population density and mobility were both higher in the eighteenth century, thus increasing the risk of dying from infection as a child. There are, however, differences in child mortality between the eighteenth-century populations, where small parishes have lower relative child-mortality rates than large parishes. This phenomenon further supports that child mortality is highly connected to population density and that low numbers of

children in skeletal assemblages are not necessarily the result of taphonomic loss. The high age non-dependent mortality in the LN–EBA sample is primarily considered to be reflective of high frequencies of violence in this society.

## Acknowledgements

Thank you to the Berit Wallenberg Foundation (grant numbers BWS 2011.0074 and BWS 2015.0044), The Rise Project, University of Gothenburg supported by ERC and the Ebbe Kock Foundation (grant numbers EK2012.0058 and EK20150038) for generous financial contributions for radiocarbon dates. Thanks also to Professor Torbjörn Ahlström, Associate Professor Jan Apel, and Adam Boethius for comments and help with improvements on the manuscript.



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Paper V





# Care and consequences of traumatic brain injury in Neolithic Sweden: A case study of ante mortem skull trauma and brain injury addressed through the bioarchaeology of care

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## Funding information

Ebbe Kock Foundation, Grant/Award Number: EK20150038

## Abstract

A number of papers have provided insight into frequencies of violence-related trauma, especially skull trauma, in Northern European skeletal assemblages dating to the Neolithic and Bronze Age. Although the cases are often well described, they lack further discussion about the consequences of skull trauma for the injured individual and the implications for the surrounding society, especially considering severe skull trauma leading to traumatic brain injuries. In this paper, we address questions of trauma and care for one individual associated with the Swedish–Norwegian Battle Axe Culture who suffered from 2 severe ante mortem skull traumas probably leading to brain injuries. These questions are addressed using the Web-based application and analytic tool *Index of Care*. We found that daily care, both short term with basic needs such as nutrition and grooming and long term with cognitive impairments, was available in the Neolithic society. Considering the frequent number of ante mortem skull trauma in the Neolithic and Bronze Age skeletal assemblages, traumatic brain injury was probably a common phenomenon. We argue that the care provided was a necessity for survival and maintenance of a socially sustainable society.

## KEYWORDS

Battle Axe Culture, bioarchaeology of care, interpersonal violence, Neolithic, skull trauma, transition analysis, traumatic brain injury

## 1 | INTRODUCTION

Fractures in bones can be caused by both accidents and interpersonal violence. This is also true regarding trauma to the skull, sometimes leading to brain injury. The external causes vary with time, as culture and the threats of external forces change. In the last century, the major causes for traumatic brain injury (TBI), that is, an injury caused by external force, have been repeatedly reported as motor vehicle and fall accidents (Hyder, Wunderlich, Puvanachandra, Gururaj, & Kobusingye, 2007).

However, ethnographic studies of the pastoralists of the Turkana society in Eastern Africa show that in nonautomobile traffic communities, skull traumas of different severity are highly associated with violence (Harrod, Liénard, & Martin, 2012). The composition of bone, with organic collagen that provides flexibility and inorganic hydroxyapatite providing strength, results in a very durable material (Pearson & Lieberman, 2004; White, Black, & Folkens, 2012). Bones are fractured when stressed over the limit of the bones' elasticity. The amount of force that a bone can endure without breaking is dependent on a

number of things, for example, bone type, kind of force, age, other pathological conditions, and location of injury (Symes, L'Abbé, Chapman, Wolff, & Dirkmaat, 2014). This kind of heavy force to the head can also affect the brain, leading to a TBI.

Skull traumas are reported as frequently occurring in Middle Neolithic contexts in Sweden and Denmark (Fibiger, Ahlström, Bennike, & Schulting, 2013) and Bronze Age contexts in central Norway (Fyllingen, 2003) and northern Germany (Jantzen et al., 2015). A majority of traumas have occurred ante mortem and show different degrees of healing in the assemblages. In traditional bioarchaeology, there has been an avoidance of discussions about consequences of injury in past populations, probably due to the field's heavy reliance on quantitative data, which directly excludes an incorporation of qualitative data from other disciplines. The risk of this kind of avoidance is a situation where there are many reported cases of trauma, but no knowledge and understanding of past health and the impact of traumatic injury for the injured and his society. Roberts (2011) however argues that a holistic approach to ill health is essential to understand the impact of disease on individuals and their

communities, which is also our goal in this paper. The social consequences of traumatic injury are here the focus point of research, as suggested by Judd and Redfern (2011).

In this article, we aim to evaluate ante mortem skull trauma and TBI in one individual from the late part of the Swedish–Norwegian Battle Axe Culture (BAC) from the site Östra Torp 4 in southernmost Sweden. In what way do the biological conditions, in relation to the social setting the individual lived in, affect the outcome of a TBI? What kinds of problems could these injuries have resulted in, and what kind of care would have been necessary for the individual's outcome, in both the acute phase and long term? The study is primarily case based, and injury and caregiving is evaluated using the *Index of Care* (Tilley, 2015; Tilley & Cameron, 2014; Tilley & Oxenham, 2011).

### 1.1 | The Swedish–Norwegian Battle Axe Culture— an archaeological background

The Swedish–Norwegian BAC (ca. 2800–2300 BC) is part of the Corded Ware Complex of Central Europe. Much of the material culture shares close resemblance; however, there are regional and temporal differences within the Corded Ware phenomenon (Furholt, 2014). Scholars have been debating if this cultural complex, which differs significantly from the previous Funnelbeaker culture (Trichterbecherkultur), have developed locally (e.g., Damm, 1991; Fokkens, 1998; Malmer, 1962) or spread through migrations (e.g., Kristiansen, 1989). Recent studies, however, provide strong indications for genetic influx from the Yamnaya on the eastern steppes, favouring the migration theory (Allentoft et al., 2015; Haak et al., 2015; Lazaridis et al., 2014). However, it seems clear that the cultural change between the Trichterbecherkultur and the BAC was also a matter of local transformation, possibly related to a change in subsistence.

The subsistence and habitation of the BAC in Scania are somewhat unclear. There are no traces of permanent settlements from the beginning of the period, indicating a mobile lifestyle. Malmer, Adamsen, and Ebbesen (1986) argued that the BAC settlements were situated where agricultural activities have been intense in modern times and thus taphonomically lost. Visible permanent settlements however do appear at the shift to the Late Neolithic around 2300 BC (Andersson, 2003; Larsson, 1992), speaking against Malmer's hypothesis. The BAC people are often thought of as some sort of nomadic herders (Andersson, 2003), which also coincides with the subsistence strategies of the Yamnaya (Anthony, 2007). There are some evidence for agricultural activities such as imprints of grain in ceramic vessels, an increase in sheep bones, and a more open landscape as a result of increased grazing areas, during the late part of the Middle Neolithic B (Andersson, 2003). This corresponds to a more settled habitation practice than evident during the early part of the BAC.

The graves during the BAC are considered to be constructed in relation to strict forms as for burial goods and position in the grave. The individuals are inhumed in single or double flat burials with no archaeologically evident indication above ground except for maybe a small cairn (Malmer, 1962). The individuals are inhumed in flexed positions, facing east. The males are buried on their left side with the head to the north and the females on their right side with their heads to the south. The grave goods are also sex specific, and weapons are linked to

the male domain and jewellery to the female. Pottery is associated with both sexes (Malmer, 1962). Olausson (2015) however shows that there are many exceptions to Malmer's rules and that the positions in the graves are not as strict as he argues. There is also evidence of probable burials in passage graves and dolmens as well as cremations, and examples of graves with more than two inhumations (Berggren & Brink, 2010; Olausson, 2014; Olausson, 2015). Further, jewellery is not only associated to female burials and flint axes only associated with male burials. The battle axe, however, has not been found in any female grave where sex could be osteologically determined and could thus be a reliable indicator of male burials. The battle axe that is only found in male graves has been interpreted as a cultural expression of a warrior ideal. Considering a weak neck construction, the axe itself has been interpreted as status item and, if used, only so for ritual fighting (Malmer, 1962). Berggren and Brink (2010) mean that burials from the later part of the BAC are less strictly organised than the ones from the early part. It is possible that there was of less importance to display cultural identity when the BAC had become well established.

There are a number of indications that the BAC, or the larger complex of the Corded Ware Culture, suffered from several occasions of interpersonal conflicts, the most reliable source being skeletal remains with violence-related trauma. Haak et al. (2008) reported family graves from Eulau in Germany where the skeletal remains indicate perimortem skull fractures, probably associated with stone axes, and a find of a flint arrowhead imbedded in a lumbar vertebra in one of the individuals. From Scania, one individual from the site Kvarteret Bronsxyan in Malmö suffered from violence-related ante mortem trauma (Berggren & Brink, 2010; Brink, 2009), and an individual from the Scanian site of Tygelsjö, dated to the late BAC (2465–2200 cal BC, LuS 11847), was killed by an antler pickaxe that was still embedded in the crania when found in the 19th century by the Swedish naturalist Sven Nilsson. A male from the site of Viby suffered from no less than three skull traumas, two being ante mortem traumas and one probably being the cause of death (Figure 1).



**FIGURE 1** Individual from the Scanian site Viby with two ante mortem traumas (only one, on the left frontal lobe, vaguely visible in the photo and indicated with an arrow) and the probable cause of death, perhaps caused by a blow from a stone axe Photo: Anna Tornberg [Colour figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

## 2 | MATERIAL AND METHODS

### 2.1 | Material

An individual from the Scanian site Östra Torp 4 was selected for analysis. The individual has been  $^{14}\text{C}$ -dated to 2475–2334 cal BC (1 sigma, UBA-30562). The individual was analysed through the Web-based application Index of Care as suggested by Tilley and Cameron (2014).

The grave was situated in a coastal area with a large number of other known BAC–Bronze Age burials. The individual, a male, was buried in a crouching position on his left side. The orientation of the skeleton cannot be distinguished because the documentation lacks indication for north. However, the left-sided position in the grave could indicate that he was placed with the head to the north, facing east, as is considered traditional for male burials. A hollow-edged flint axe, three flint blades, and some pottery were found in the grave filling. However, only the flint axe could be directly linked to the burial. The location of the finds could not be distinguished because the grave had already started to crumble when the archaeologist arrived. No battle axe was found in association to the burial.

The individual died at the age of 45–90 years (Figure 2). The first part of the age span is considered more probable than the late part, depending on bone structure and tooth attrition, which are not considered in a transition analysis. He was robustly built with a stature of 175–180 cm. This is somewhat over the average male stature of 173 cm in Scania from the same period (Tornberg, 2018). The individual had a  $\delta^{13}\text{C}$  value of  $-19.8$  and a  $\delta^{15}\text{N}$  value of  $10.6$ . Animal isotopic signals from the same area, dated to the Late Bronze Age (ca. 900 BC), have a  $\delta^{13}\text{C}$  signal of  $-20.99$  ( $SD = 0.44$ ), which is supposed to show the isotopic signal of a completely terrestrial diet in the area. The protein contribution to the diet of Östra Torp 4 is therefore interpreted as being terrestrial with a marine influence and predominantly based on animal products, possibly reflecting a coastal habitat where fish would be easily accessible. This is also reflected in the somewhat increased  $\delta^{15}\text{N}$  values of  $10.6$ . The subsistence of the BAC is considered primarily based on pastoralism but with some agriculture as well. The marine influx in the Östra Torp 4 individual is not consistent with the results by Fornander (2013), who suggests no, or very limited, marine contribution in south-western Scania during the BAC. However, the sources of carbohydrates or fats are poorly understood through stable isotopes

in collagen because these studies only pinpoint the composition of the protein (Ambrose & Norr, 1993; Jim, Ambrose, & Evershed, 2004; Schwarcz, 2002; Sjögren & Price, 2013). Therefore, the amount of grain in the diet could have been higher than indicated by the isotopic signals. Analyses of dental caries could however indicate the amount of carbohydrates in the diet, as there is a correlation between consumption of carbohydrates and the presence of dental caries (Gibson & Williams, 1999; Touger-Decker & van Loveren, 2003). The individual from Östra Torp 4 did not however suffer from dental caries and had only low–moderate calculus deposits. All teeth except the left upper first incisor could be examined. The incisor was lost post mortem.

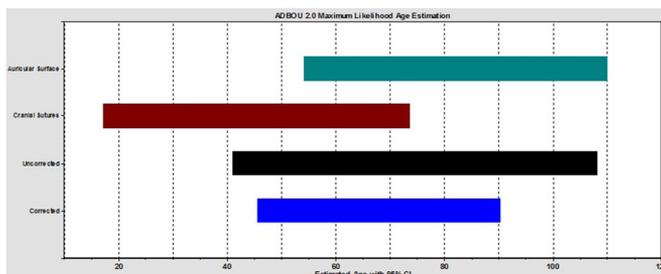
The individual was buried in a coastal area, and it is possible that the settlement where he lived was located nearby. Fornander (2013) provides evidence of moderate mobility among the BAC individuals. It is possible that this is connected to a pastoral subsistence.

### 2.2 | Bioarchaeological methods

Biological sex was assessed using the curvature of the *incisura ischiadica major* on the iliac bone as well as on skull morphology according to Buikstra, Ubelaker, Aftandilian, and Haas (1994). Age at death was estimated using transitions analysis (Boldsen, Milner, Konigsberg, & Wood, 2002; Milner & Boldsen, 2012) using an archaeological population as a prior. The pubic bone was taphonomically damaged on both sides and could not be used for sex and age estimations, resulting in longer age intervals in the transitions analysis and generally less reliable sex estimation. Together with secondary sex characteristics of the skull and a robust skeleton as a whole, the individual is however considered as clearly male.

Palaeopathology was examined ocularly under a bright light. A magnifying glass was used to register small features related to healing, but no additional tools were considered necessary. Dental caries was registered as present when a real cavity could be detected and absent when no cavity could be seen. Dental calculus was registered as mild, medium, and severe when present.

All long bones were measured according to Martin and Saller (1957). Stature was estimated using Sjøvold (1990) on the tibia length (Martin 1b) because none of the femora were suitable for stature estimations.



**FIGURE 2** Diagram of maximum likelihood age estimation (years) of the individual at Östra Torp 4, using transition analysis in the ADBOU database [Colour figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

The chronology was established using accelerator mass spectrometry  $^{14}\text{C}$  dating on a tooth root. The radiocarbon dating was conducted by the accelerator mass spectrometry  $^{14}\text{C}$  CHRONO Laboratory at Queens University, Belfast. The same laboratory also provided stable isotopes of  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  for dietary reconstruction.

The sample consisted of a permanent premolar tooth; thus, the results of the analysis mirror childhood diet corresponding to when the tooth was formed. The sample was pretreated using a simple acid-base-acid treatment followed by gelatinisation and ultrafiltration with a Vivaspin filter cleaning method (Reimer, Hoper, MacDonald, Reimer, & Thompson, 2015). Analyses of stable isotopes of carbon and nitrogen in bone collagen reflect the protein contribution to the diet (Hedges & Reynard, 2007). The value of  $\delta^{13}\text{C}$  is mirrored if the diet was predominantly marine or terrestrial (Schoeninger & DeNiro, 1984; Van der Merwe, 1982). Eriksson and Lidén (2013) report values of less than  $-20\%$  as entirely terrestrial and up to  $-12\%$  as entirely marine for northern Europe.  $\delta^{15}\text{N}$  reflect trophic level, where an enrichment of  $\sim 3\%$  along the food chain is commonly reported. A land-living carnivore preying on herbivores would then have a  $\delta^{15}\text{N}$  value of  $\sim 9\%$  (Eriksson & Lidén, 2013; Schoeninger & DeNiro, 1984). O'Connell, Kneale, Tasevska, and Kuhnle (2012) however found that an enrichment of up to  $6\%$  is possible, with an overestimation of animal protein in the diet as a result, and an enrichment of  $3\text{--}6\%$  should be considered.

### 2.3 | The Index of Care—a short introduction to the application

Caregiving at different levels can be seen as part of being human. Because of this, Lorna Tilley (2015) has developed a way to study care and caregiving in past populations. She means that care is a conscious act that includes both caretakers and caregivers, and the study of care could therefore tell us something about social relations and societies in the past (Tilley, 2015). She calls this the *Bioarchaeology of Care*.

The bioarchaeology of care can be assessed through a Web-based application that provides an index of care. The index of care is largely divided into four steps of documenting an interpretation. The application is Web based and is accessible through <http://www.indexofcare.org/>, and this is where the individual case is documented and interpreted. The four steps are divided as follows (Tilley & Cameron, 2014):

- Step 1: Describe, diagnose, document
- Step 2: Determine disability
- Step 3: Construct the model of care
- Step 4: Interpretation

This means that the skeletal remains and all palaeopathological and additional features are documented, described, and diagnosed in the first step. In the second step, an interpretation of disability is constructed, that is, to identify the pathological condition's impact on everyday life. In the third step, the degree and type of care needed for the affected are evaluated. In the last step, an interpretation of the implications on the individual and collective is made. For further insight into the index of care, we recommend the website and the guide written by Tilley and Cameron (2014).

The index-of-care approach is considered well suited for studies of TBI in prehistory because it acknowledges documentation of several aspects that affect individual health, interpretations of care needed and provided, and the implication on both individual and collective planes in relation to the social setting.

## 3 | STEP 1: DESCRIBE, DIAGNOSE, AND DOCUMENT

### 3.1 | Physical pathologies

The individual suffered from an oblique fracture at approximately the midbody of the right clavicle. The fracture was well healed at the time of death but with a residual deformity resulting in some shortening. It is not likely that the clavicle fracture caused any abiding complications for the individual because clavicle fractures, even with some shortening, often do not cause any reduced mobility and strength in the long term (Nowak, 2002; Rosenberg, Neumann, & Wallace, 2007), although some pain can remain also after several years (Rosenberg et al., 2007).

An ante mortem trauma was detected on the right frontal lobe. The trauma measured approximately  $30 \times 18 \text{ mm}$  and was probably caused by a blow of a blunt, or semisharp, object. A sharp and well-defined edge was visible to the posterior, well correlated to the edge of a battle axe of Malmer's Type D (Figure 3). The trauma showed significant healing, with death occurring months or even years after



**FIGURE 3** Battle axe of Malmer's Type D (a) with good fitting with the lesion (b) Photo: Anna Tornberg [Colour figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

trauma. Dense bone was present at the previous diploe area, however with some remnants of the diploic structure present at a smaller area around the edge (Figure 4).

In addition to the trauma on the right frontal lobe, there was an ante mortem, circular, trauma to the left parietal lobe (Figure 5), also affecting a small portion of the frontal bone. The trauma measures



**FIGURE 4** Frontal trauma probably caused by a blow of a battle axe  
Photo: Anna Tornberg [Colour figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]



**FIGURE 5** A 30 × 30-mm circular ante mortem trauma on the left parietal lobe penetrating the outer table and diploe. Smooth rims and complete loss of visible diploic structure is consistent with substantial healing, evidencing long-time survival  
Photo: Anna Tornberg [Colour figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

30 × 30 mm, is about 6 mm deep, and runs through the coronal suture. The trauma penetrates both the outer table and the diploe, but only a small portion of the inner table, where the skull is completely penetrated. The trauma demonstrates significant healing, probably months or years, with smooth rims and no visible diploe or remains of the coronal suture. Dense bone and a few dense bone spicules are present at the bottom of the depression. The bone spicules might be associated to healed inflammatory activity. Nerlich, Peschel, Zink, and Rösing (2003) show that there are large differences between the healing rate associated to skull traumas and the healing rate in other bones. This is due to the lack of mechanical strain in skulls, otherwise helping the ossification process. It is therefore difficult to assess the survival time after injury for the individual. However, Nerlich et al. show that survival only days after injury does not show any sign of healing or osteoclastic resorption, and the individuals displaying smoothed rims and loss of diploic structure are likely to have survived for years. It is therefore likely that the individual from Östra Torp 4 survived one or several years post injury. There is no visible damage to the inner table except for the portion that has been penetrated. The trauma is considered as caused by a blunt object, and the shape of the depression correlates well with the knob at the neck of a battle axe of Malmer's Type D (Figure 6). A differential diagnosis would be trepanation. This is however considered to be less likely because the trauma only penetrates a small part of the inner table. Andrushko and Verano (2008) on the other hand showed that only 16.1% ( $n = 411$ ) of the trepanned individuals from Peruvian Cuzco had at least one trepanation that perforated both the inner and outer tables of the skull. They further found a highly significant correlation between skull trauma and trepanation, as well as a high survival rate (83%), indicating that TBI might have been present also among these individuals.

It is plausible that the two skull traumas are from the same event and due to a blow from the same weapon. A backhand blow to the frontal region was probably first because the blow to the parietal region must have caused unconsciousness. If the parietal trauma was caused by the first blow, it probably struck the attacked to the ground.



**FIGURE 6** The neck of a battle axe of Malmer's Type D. The round neck is of similar shape and dimension as the parietal trauma and might therefore have been used as a weapon to inflict the trauma  
Photo: Anna Tornberg [Colour figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

Then the frontal trauma must have been caused by a blow from behind when the attacked was lying down.

### 3.2 | Neurological and neuropsychological considerations

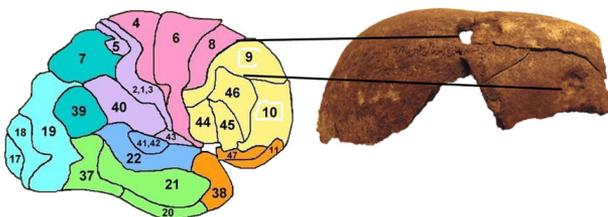
The frontoparietal trauma is identified as a penetrating injury that most probably resulted in injuries on intracerebral tissues. The injury is situated in the left hemisphere, relatively near the border to the right hemisphere and almost crossing the *fissura coronalis*. The central sulcus, where primary projection zones for motor and sensory areas are located, seems affected, eventually more so for the motor cortex (Figure 7). Both motor and sensory cortices are lateralised and hence more likely affecting motor and sensory functions on the right side of the body. Furthermore, the primary motor and sensory projection zones are topographically distributed with uneven proportions regarding the representations of body parts. This means that more sensitive and fine motor controlled parts, such as the mouth or hands, are represented on a larger part of the projection area in the brain.

The frontal trauma is not penetrating and located quite near the temple on the right side of the skull. This area is known as the prefrontal cortex, and injuries have been connected to affect higher cognitive functions, that is, more likely functions as spatial memory or new learning. As there is a differentiation between the left and right prefrontal regions, the localisation of injury might have caused disabilities in attention and social cognition (Miller, 2007). The complex construct *social cognition* concerns the ability to understand and react adequately in interaction to the behaviour of other people in social situations, it means among other things difficulties in perspective shifting (Rankin, 2007). Injuries closer to the medial prefrontal cortex have been associated to altered emotional states and impaired social behaviour (Rankin, 2007). Closed head injury is always associated with diffuse damage, known as diffuse axonal injury. Diffuse axonal injury affects white matter tracts and often involves the frontal lobes, the corpus callosum, and the corona radiata. There is also a possibility for countercoup effects, when the impulse from trauma in closed head injury can spread through the brain and cause injuries on the opposite end of the cranium (Kolb & Whishaw, 2009). Further on, the penetrating wound could lessen the risk of elevating pressure to the brain. On the other hand, the risk of external sources for infections could be exceeding and added to the risk of the frequent acknowledged susceptibility of the breakdown in the blood–brain barrier protection. However, the osteological evidence indicates that, in this case, neither of the mentioned risks has had a definitive impact on survival.

## 4 | STEP 2: CONSIDERATIONS ON DISABILITY

We nowadays acknowledge the brain as the primary centre for mental processes. Neuropsychology, the domain within the field of psychology that specifically focuses on the relation between brain functions and behaviour, has made considerable progress during the 20th century. An overview of the history of the neuropsychological domain exceeds the limited space in this article, and interested readers are referred to, for example, Kolb and Whishaw (2009) and Lezak (2012). However, it is generally recognised that the relation between brain functions and behaviour is extremely complex. The complexity on an individual level is even more pronounced as, for example, the circumstances during ontogeny are individually different. It is also proven that individuals with similar lesions after a TBI may have different neuropsychological consequences. These consequences are often conceptualised in three systems: (a) cognition, (b) emotionality, and (c) executive functions (Lezak, 2012). The cognitive functions have gained more attention within neuropsychology and are more easily conceptualised and measured compared with emotions and executive behaviour. Cognition is commonly described as the ability to receive, process, and use information. Subdivisions of cognition processes are mainly attention, memory, language, problem solving, learning, and decision ability. Although there are great individual diversity regarding potential dysfunctions after TBI, there are also some generally more common relationship between site of injury and behavioural consequences; for example, language is more often affected after injury to the left hemisphere, and attention difficulties are more expected when the right hemisphere is damaged.

The considerable similarity between brains of different species implies a phylogenetic evolution, which among other things makes it sane to make inferences between other species and man (Kolb & Whishaw, 2009). Aleksandr Luria (1973) conceptualises the marks from the evolution on the brain functions in three blocks: (a) a unit, regarded as the relative phylogenetic oldest part, that regulates tone or waking; (b) a unit mainly associated with posterior parts of the brain (temporal, parietal, and occipital lobes) and concerned with obtaining, processing, and storing information that arrives via sensory organs from the outside world; and (c) a unit mainly associated with the frontal lobe, the part considered to be the phylogenetic youngest part of the human brain, and concerned with programming, regulating, and verifying mental activity, also conceptualised as vital aspects of executive functions. A more detailed description for the frontal lobe, for the sake of the focus in this article, can be extensively found in, for example, Miller and Cummings (2007). The frontal lobe can be divided into



**FIGURE 7** Location of the traumas in relation to Brodmann areas. Injuries to yellow areas correspond to risks of executive dysfunctions and pink areas correspond to risk for motor dysfunctions [Colour figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

the primary motor and premotor areas as more distinctive functional units for motor functions, whereas the prefrontal cortex is more complex. Prefrontal regions can be further divided into four functional units: (a) executive cognitive functions considered primarily to be mediated by the lateral prefrontal cortex; (b) behavioural-emotional self-regulatory and (c) energisation regulating functions, which are both primarily mediated by the ventral medial prefrontal cortex; and finally (d) metacognitive processes associated to the frontal polar region (Stuss, 2007). Another feature of brain function is known as lateralisation; that is, each of the hemispheres mainly responds to the opposite side of the body and sensory surroundings (Kolb & Whishaw, 2009).

The theory by Luria implied that the individual behaviour, and thereby brain functions, could only be understood if both the phylogenetic and ontogenetic aspects were considered. Several investigations, some in cooperation with Lev Vygotsky (Luria, 1973; Luria, Vygotskij, & Rossiter, 1992), were conducted with aims to reveal the importance of culture on behaviour. As Toomela (2003) presents the idea expressed by Ardila: "the human brain possesses certain basic capabilities, i.e. ways of processing information, and second, culture provides content to these capabilities" (Toomela, 2003). This citation is suggested as the rationale for the neuropsychological considerations regarding the case in this article.

It is known in modern medicine that severe skull traumas often cause a TBI. The TBI is commonly classified according to level of consciousness at, or near in time to, the injury in three categories of severity: mild, moderate, and severe (Roebuck-Spencer & Cernich, 2014). Usually, the TBI is divided into a primary damage associated with the results at impact, and the secondary consequences of reaction within the brain as well as extracerebral insults, such as hypotension, swelling, axonal injury, and inflammation (Kochanek et al., 2007). The TBI can be either closed, that is, the trauma has not caused open access to the brain, or open, that is, the damage has penetrated the skull bones and usually caused a focal injury. Presently, TBI is considered to be the leading cause of death and disability (Roebuck-Spencer & Cernich, 2014), affecting both physical and psychological health, as well as psychosocial relations. Among those with moderate to severe TBI, common symptoms are irritability, temper, dizziness, sensitivity to noise, blurred vision, lack of initiative, fatigue, and impairments in attention, processing speed, learning, and memory (Griffen & Hanks, 2014). Outcome from TBI varies considerably, but regaining of functions is most pronounced during the first 5–6 months. Long-term outcome is still a research area, but initial injury severity tends to have less impact as times goes by (Wood, 2008). However, it is commonly acknowledged that the problems of the injured affect the social surroundings as well as get affected by it. Therefore, studying TBI in prehistory gives insights into the physiological and psychological problems linked to the injury at that time, as well as the past social surrounding providing adequate care for the injured.

#### 4.1 | Acute

The open wounds would have been susceptible for infections. The parietal trauma exhibits a few bone spicules possibly related to a

healed inflammatory process. However, there is no further evidence of bone resorption or remodelling indicating severe and prolonged infection of the wound. It is likely that the injuries would have caused some time of unconsciousness and the parietal injury would probably cause dysfunctions on the right upper part of the body, for example, the neck, shoulder, and arm. A considerable amount of acute care would be expected, from basic nursing to guiding and successive meeting demands of orientation to time and place.

#### 4.2 | Long term

The healing of skull traumas is generally slow and does not include bone reunion as in long bones but is rather visible as smoothening of the rim of the fracture and a nonvisible diploe, which is detectable at the earliest several months, but more likely after one or several years (Nerlich et al., 2003). Recovery is expected to be more pronounced during the first months, but there is also great variability. Early in the recovery, functional abilities such as levels of interdependency in different activities, for example, manageability in self-care, are prominent, whereas outcome in a later phase is more often described in terms of social role fulfilment. This later phase concerns the ambition to return to an optimal level of participation in the community, a participation that includes relationships with others, independence in daily living, and meaningful activities. This could have included pastoral activities such as herding and activities related to flint-knapping, community protector, and raiding. It is also likely that these societies were involved in trade with other groups (Malmer, 1989, p. 10), which could have been obstructed. Considering that there is no evidence for skeletal atrophy, it is plausible that the individual did not suffer from any long-term immobility. There is thereby a possibility that this individual regained base management in self-care, but it is more uncertain on the degree of fulfilment in social participation.

The well-known case of Phineas Gage, who suffered a penetrating TBI in 1848, reveals that even a severe TBI can result in relative good functional outcome, but also a substantial lack of social cognition. In a nomad, or seminomad, society as the Swedish-Norwegian BAC, problems with spatial orientation must have been very disabling, and it is plausible that support from the surrounding was necessary. This could for example include travelling together with others at all time. Difficulties with handling sequences in complex activities would have been problematic in food procurement because this takes planning in several steps with the output available in the future. Being able to stay alive and sustain a full member of the society would have necessitated different kinds of help from the surrounding, probably on a daily basis. The long-term consequences after TBI are, even today, uncertain. However, there are a number of studies that indicate that the long-term outcome might be better than previously expected (Jacobsson, Westerberg, Söderberg, & Lexell, 2009; Wood, 2008; Wood & Rutterford, 2006). Considering the injuries in this case, the expectations for full recovery are more unlikely and, even if functions related to activities in daily routines are fulfilled, the more subtle consequences are expected to remain.

## 5 | STEP 3: CONSTRUCT A MODEL OF CARE

### 5.1 | Short-term care

The individual from Östra Torp 4 probably needed intensive care for the first weeks after injury because bleeding and infections were acute hazards. Surgical cleaning and removal of shattered bone was probably practised considering neat surfaces. This procedure is similar to that of trepanations. Trepanations as treatment of skull fractures and for minimising the effects of TBI have been suggested by Jolly and Kurin (2017). Care in a clean environment with regular attention to the wound, possibly also using some sort of antiseptic, must have been upheld to limit bacterial infections. Survival for a few weeks up to several months or years is also documented from North American scalping cases where 24% of 33 victims showed signs of healing (Case, 1995). Bergqvist (2013) suggests that, at least in medieval Sweden, beer was probably used to clean wounds as it contains alcohol, hops, and honey, which all have antiseptic qualities. The injured would probably have been unconscious immediately after injury and for several days or weeks needing care and assistance for rudimentary activities, for example, grooming and nutrition. There is no skeletal evidence (such as dental caries, dental calculus, or atrophy) for long-term masticatory problems or immobility, indicating that the individual remained unconscious for a limited time.

### 5.2 | Long-term care

As time evolves, the situation changes from basic needs to more social and interactional necessities. The injured individual has to integrate to the society with varying degrees of functional impairments. It is plausible that this individual would have some motor and/or sensory constraints while the TBI affects the right side of the body. It is possible that he, in a relatively short time, would regain walking capabilities. However, initially, he most probably would have needed assistance to get to some place to relieve himself, or to wash up. Because no atrophy is present, it is plausible that problems with sensory and motor skills have been limited and that the individual would still have been able to use the limbs. However, problems with fine motor skills would be undetectable in the skeleton but would cause problems in, for example, the finer segments of flint knapping, wood working, or sewing. There is no evident difference in dental calculus between sides that could indicate paralysis on one side due to cerebral haemorrhage. Further, it is plausible that he would have stayed close to near surroundings considering possible difficulties in spatial orientation in relation to the TBI. This would have had a direct social impact of the individual because the BAC is often associated to a relatively high degree of mobility. It is likely that the individual would have needed help from others to be able to function within a nomadic society. The trauma might also have had an impact on handling sequences in more complex activities, especially considering new learning where long-known, routine performances, could not be generated as help for executing a task. As the osteological analysis shows that this individual has survived for a lengthier time, it is plausible that the society has supported some kind of rehabilitation efforts in the recovery and reintegration to society.

## 6 | STEP 4: INTERPRETATION

Violence and skull traumas have been reported in North European skeletal assemblages dating to the Neolithic and Bronze Age (Fibiger et al., 2013; Fyllingen, 2003; Jantzen et al., 2015). Fibiger et al. (2013) report frequencies of skull trauma (including the mandible) of 9.4% and 16.9% in 378 individuals in Neolithic Sweden and Denmark, respectively, where ante mortem traumas were more frequently occurring among males. Milner, Boldsen, Weise, Lauritsen, and Freund (2015) further conclude that frequencies of ante mortem trauma do not increase relative to higher age in medieval Denmark. Instead, people suffering from ante mortem trauma seem to have an increased risk of dying, either by greater exposure to dangerous situations or because of disabilities due to the initial trauma, the latter especially considering severe skull trauma causing TBIs (Milner et al., 2015). Considering that evidence of skull trauma is frequent in skeletal assemblages, many individuals probably also suffered from a TBI. As Jolly and Kurin (2017) acknowledge, most ancient trepanation cases should be considered as possibly having been suffering from TBI. To be able to gain knowledge of the implications of high frequencies of skull trauma in past societies, on both an individual plane and a societal plane, a holistic approach to health within bioarchaeology as well as the necessity of an inclusion of qualitative data from contemporary medicine is here argued for. The individual from Östra Torp 4 demonstrated two healed severe skull traumas where the severity of the injuries indicates TBI. The traumas have affected the individual and society differently in the acute phase and long term. The different stages in trauma and recovery also demand different kinds of care.

### 6.1 | Social relations, practice, and organisation

The demands on our cognitive abilities and social capabilities vary with culture (Toomela, 2003). Current knowledge on outcome after TBI states that there is a great variability in the long term and that initial severity may be less influential on outcome as time passes, which could mean that cultural demands might be more important. That is, in a society where there are no clocks, problems with being in time might not be a problem. There is no skeletal evidence of difficulties in association to TBI in the remains of the individual from Östra Torp 4, for example, masticatory problems or impaired walking capacity, but there were probably long-term cognitive problems that had to be considered and solved by the community.

The care provided from the people surrounding the male individual from Östra Torp 4 demonstrates a collective that had some knowledge and understanding in the importance of clean environments for survival of the injured. Because of the relatively high frequencies in skull trauma in Neolithic Sweden and Denmark (Fibiger et al., 2013), as well as several reported skull traumas from BAC burials (see Section 1.1), we suggest that care associated to these kinds of trauma was commonly practised by Neolithic people and therefore relatively well developed. Considering the severity of the traumas, we consider it more likely that these injuries were caused by conflict-related interpersonal violence rather than by violence of ritual or entertainment character, although this is also possible.

The community invested a lot of time in caring for the wounded and provided him with nutrition and help with hygiene probably several times every day as well as continued to see the individual as a part of the society even though he needed some help and attention also a long time after the acute phase. It seems clear that it has been a socially sustainable society. A socially sustainable society could be expressed as "the basic conditions that are necessary for the [...] social systems to not systematically degrade, so that the opportunity to meet needs remain" (Missimer, 2015). In a society where all individuals would have played an important role for sustaining enough nutrition and possibly protection, caring for them in the best possible way would have been one of the basic conditions. It is difficult to encourage parts of the society to contribute if the contribution would not provide some sort of guarantee for care when needed. The caring for individual survival and resocialisation is thus a necessity for the survival and maintenance of the group.

Considering the amount of healed severe skull traumas in Neolithic southern Scandinavia, it is plausible that many of the individuals suffered from a TBI. This also implies that care for these individuals could be upheld by others in the society in both the acute phase and long term. The different kinds of care differ distinctly between these phases. Although traditional bioarchaeological research tends to focus only on the acute phase and skeletal modifications, an application of the Index of Care and integration of neuropsychological knowledge from modern cases can provide a suggestion of care long term also for skull trauma, resulting in deeper insight in past societies. It is possible that TBIs did not cause as much limitations and difficulties in prehistoric societies as in modern highly technological societies; however, problems with motor skills, sequences, and spatial orientations had to be addressed and solved, for example, through changed responsibilities. This long-term manipulation of chores for a lengthier time of months or years could have included a shift from activities demanding fine motor skills such as flint knapping to more mechanical work such as taking care of domestic animals. This could also have included a need for travel companion for the affected individual at all times to compensate for problems with spatial orientation. This would have included a reorganisation of labour as well as an increased workload for the other people within the community. Considering that there are no skeletal signs of prolonged physical impairment, it is plausible that the individual could remain a protector of the social group against aggressors in the long term, which means that this would only have been compensated for in the initial phase of weeks or maybe months.

## 6.2 | Group and individual identity

Malmer (1962, pp. 660 ff) argues that the battle axes that are associated to the BAC were not used in fighting as they have a tendency to break at the shaft. Kristiansen et al. (2017), on the other hand, discuss the possibility of small warrior bands of young males to play big parts of a population expansion from the Pontic-Caspian steppe, which contributed to the development of the Corded Ware/BAC in Central and Northern Europe. Considering that battle axes are often associated to burials, thus identity, in the Swedish-Norwegian BAC, it is likely that there was in fact a warrior ethos within this population.

The male from Östra Torp 4 was taller than average and robustly built and must have been an important member of the society. The two traumas of the individual from Östra Torp 4 show a good fit to the edge and the neck of a battle axe of Malmer's Type D, speaking against the battle axe being only a ceremonial weapon. Considering the stature and robustness of the individual, it is possible that the injuries are related a previous position as a "warrior" or protector. The male was buried in accordance to social norms, which shows that the individual was still a functioning part of the community; however, the lack of a battle axe might reflect the individual as no longer being a warrior. Even though battle axes are only associated to males, they are only found in one out of 11 male burials where sex have been osteologically determined (Olausson, 2015). This suggests that the battle axe has been available in burial for only a very few individuals in the society.

It is evident that the possibility of many different types of care was present in the BAC society. The individual could remain a part of the society, demonstrated by long-time survival and a burial in accordance with social praxis. We acknowledge this as the individual being part of a socially sustainable society where caring for the individual is a necessity for the society not to degrade.

## 7 | CONCLUSIONS

In this paper, we conclude that at least some of the ante mortem skull traumas frequently occurring in prehistory have also caused brain injury. The outcome of brain injuries is complex and tightly correspondent to social context.

The male individual from Östra Torp 4 displayed two ante mortem severe skull traumas that probably also lead to brain injuries. The affected areas are often associated with motor or sensory constraints, problems with spatial orientation, and difficulties in handling sequences in complex activities. In the acute phase, the individual would have needed care for rudimentary activities such as nutrition and grooming and was probably unconscious for some time. Bleeding and possible removing of bone splinters must have been cared for in a clean environment to avoid infections, thus showing that some knowledge or accustomedness about medicine was present. After the acute phase, help with things such as planning ahead and travelling around was probably upheld by the society. It is also possible that problems with motor or sensory skills needed adjustments in chores.

## ACKNOWLEDGEMENTS

We would like to thank the Ebbe Kock Foundation (EK20150038) for generously financing the radiocarbon date and stable isotope analysis. The authors confirm that there are no conflicts of interest related to this article.

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**How to cite this article:** Tornberg A, Jacobsson L. Care and consequences of traumatic brain injury in Neolithic Sweden: A case study of ante mortem skull trauma and brain injury addressed through the bioarchaeology of care. *Int J Osteoarchaeol*. 2018;1-11. <https://doi.org/10.1002/oa.2646>



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## Health, cattle and ploughs

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Skeletons provide unsurpassed evidence of living, and sometimes dying, in past populations. In this thesis, skeletal responses to agro-pastoral intensification are explored and discussed. Increased access to nutrition, population increase and a more complex society, affect diet and health in both positive and negative ways. In this book, skeletal remains from southern Sweden, dating to the Late Neolithic and Early Bronze Age, serve as the foundation for analysis. The study of skeletal remains provides a unique opportunity to shed light on individual and population health-consequences related to the formation of a Bronze Age society in southern Sweden.

**Anna Tornberg** is a bioarchaeologist interested in social and political-economic aspects of health in past populations. This is her doctoral thesis in Historical Osteology.



LUND  
UNIVERSITY

Historical Osteology  
Department of Archaeology and Ancient History  
ISBN 978-91-88473-85-1

ISSN 0065-0994 (Acta Archaeologica Lundensia Series Altera in 8°)  
ISSN 1654-2363 (Studies in Osteology)

