

Valkyries: Was Gender Equality High in the Scandinavian Periphery since Viking Times? Evidence from Enamel Hypoplasia and Height Ratios

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Abstract

Scandinavian countries currently have very high values of female autonomy. Was this already the case in Viking Times? In this study, we trace the roots of gender equality in the Scandinavian periphery over the past two millennia. We evaluate and recommend a new measure of early gender equality: relative enamel hypoplasia values of males and females. This new indicator allows us to trace relative health and nutritional equality, using archaeological evidence. We find that Scandinavian women in the rural periphery already had relatively good health and nutritional values during the Viking era and the medieval period thereafter. The corresponding value is 0.8 equality advantage for Scandinavian women, whereas in the rest of Europe most values fall in a band around 1.2 ratio units. This suggests that the currently high gender equality had a precedence during the Middle Ages.

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Introduction

Even after a century of progress in gender equality, there are still regions of the world economy, which are characterized by high gender inequality (Milazzo and Goldstein 2017, van Zanden et al. 2014a, World Bank 2011). In particular, developing countries in the Middle East (such as Yemen) or South Asia (for example, Pakistan) display vast differences in access to education, health, life expectancy, economic opportunities, and political empowerment (World Economic Forum 2017). But even in Europe, the differences are still substantial. Scandinavian countries are always the leading group in gender equality.

An extensive literature argues that gender equality not only increases the relative welfare of women in relatively gender-equal countries but also affects economic growth and development very positively (Sen 1992, Klasen 1999, Mammen and Paxson 2000, World Bank 2011). For example, Klasen and Lamanna (2009) study world regions between 1960 and 2000 and find that gender gaps in education and employment have a negative impact on economic growth (see the review by Milazzo and Goldstein 2017 and Ward et al. 2010). Although income growth is affected, it is not the only dimension of development impacted by gender gaps: A higher participation of females in labor markets or politics is linked to better outcomes in terms of productivity (Goldstein et al. 2015), children's nutrition (Duflo 2003), public spending (Svaleryd 2009), and reduced corruption (Dollar et al. 2001).¹ For example, Dollar et al. find that a higher share of women in parliament reduces the level of corruption, controlling for a wide array of other variables. In summary, many studies argue that while gender equality is a valuable goal on its own, it also means “smart economics” because it improves the situations of

¹ See review by Milazzo and Goldstein (2017) and Ward et al. (2010, p. 24-29).

both males and females, as concluded by the World Development Report 2012 (World Bank 2011).

However, Duflo (2012, p. 1053) summarizes the literature by emphasizing the two potential directions of causality which need to be considered: Either higher development levels could follow superior gender equality, or more gender equality could cause development (or both). This issue implies that more evidence is needed to understand the causes and effects of gender equality more thoroughly. One promising strategy for gaining further insights is to study long historical time series and paying attention to cases in which gender equality deviates from improvements in income and development (Alesina et al. 2013, Iversen and Rosenbluth 2010). For example, Dilli et al. 2015 study both short and long run determinants of gender equality in a global sample of countries for the decades 1950 to 2000. They frame their study as a debate between the modernization (or development) view and the institutional view (especially informal institutions, influencing norms and values). The modernization view is based on the first direction of causality mentioned above, that income influences gender equality. However, Dilli et al. emphasize that important outliers exist -- Qatar and Saudi Arabia are the most extreme cases where there is far lower gender equality than would be expected from the level of income. Further, East Asian countries had decreasing gender equality during the economic growth phases of the 1990s and 2000s, which represents another deviation from the income-gender equality correlation (Klasen and Wink 2004). Dilli et al. provide evidence for historical institutions that exert a strong influence, independently of income (in regression analyses). Religious institutions are obviously influential (such as extreme forms of Islamic institutions), as are family-related institutions: endogamous marriage rules (i.e. marriage within the same population group) can be interpreted as informal institutions and have a very long-

lasting impact. Legal institutions mattered during the twentieth century (for example, legal and political institutions of socialism were related with higher gender equality).²

Moving further back in history, De Moor and van Zanden (2010) have supported the view that female autonomy had a strong influence on European economic development, basing their argument on a historical description of labor markets and the legacy of medieval institutions. They argued that female autonomy was a crucial factor for early development in Northwestern European countries (for a critique, especially on endogeneity issues, see Dennison and Ogilvie 2014 and 2016; replies: Carmichael et al. 2016, de Pleijt et al. 2016).

Important gaps in our knowledge exist, especially for poor peripheral regions in early periods. For example, Scandinavia was a region of very low income per capita in the preindustrial period, whereas it is among the wealthiest regions on the planet nowadays (Bolt and van Zanden 2014). One critical piece of evidence is, hence, the differential development of gender equality in Sweden, Norway, Denmark, Finland, Iceland and Greenland, which we will study here in greater detail.

Scandinavian countries have the highest values of female autonomy today. Even if some of the usual proxy variables might not indicate perfect equality, in no other set of countries can such a high labor participation rate and a similar degree of equality in political decision making be observed (Carmichael et al. 2016, World Economic Forum 2017, World Bank 2011). Has this always been the case?

² Dilli et al. also discuss potential reverse causality, for instance, that religious and family institutions might be influenced by income. However, these informal institutions typically change very slowly, and some countries with female-friendly institutions were poor in earlier times (Northwestern Europe, for example). Other countries with less gender equal informal institutions were rich during the medieval period, Iraq for example.

In this study, we trace the roots of female autonomy over the past two millennia with a particular focus on the Viking era (late 8th to late 11th century CE) and the medieval period thereafter. The relative frequency of linear enamel hypoplasia (LEH) is used as an indicator of gender equality. LEH can be observed as horizontal grooves (or lines, as we will call them in the following) on teeth which develop in situations of malnutrition and disease during early childhood.³ In line with previous studies, we argue that if girls receive less food and healthcare than boys, their relative LEH value is higher (Guatelli-Steinberg and Lukacs 1999, Goodman et al. 1987, Oyamada et al. 2012, Irei et al., 2008, Låås and Kjellström, forthcoming).⁴ Our evidence is based on skeletons found in archaeological excavations. We study this new indicator carefully by assessing potential selection bias and comparing it with alternative gender equality indicators. For example, we find that the evidence based on the LEH ratios accords well

³ Schultz et al. (1998, p. 294-295) explain that, concerning the categorization of enamel defects, based on the classification from the *Fédération Dentaire Internationale* (1982), and consistent with the European History of Health Project (EHHP from here), Linear Enamel Hypoplasia (LEH) is classified as Type 4 in the form of horizontal grooves.

⁴ Guatelli-Steinberg and Lukacs (1999) argue that sex differences in the incidence of LEH can be used as an indicator of sex-bias investment during childhood. Several findings suggest that a higher female LEH frequency comes from male preferential treatment in access to basic resources during childhood (Goodman et al. 1987, Oyamada et al. 2012, Irei et al. 2008, Låås and Kjellström, forthcoming). However, it is complicated to demonstrate sex-biased treatment based on LEH if the sample does not provide direct evidence of environmental stress and cultural factors (such as clinical and historical records) (see Williamson 1976). Only a few studies have been able to assess sex differences in LEH based on direct evidence of stress, whereas those relying on indirect evidence –i.e., belonging to a certain “stressful” socioeconomic group- are not able to distinguish between male vulnerability/female buffering and preferential treatment. Nonetheless, Guatelli-Steinberg and Lukacs (1999, p. 118) argue that most findings that are based on direct and indirect evidence show insignificant differences between sex categories and conclude that sex differences in the incidence of LEH capture “cultural practices of sex-biased parental investment after birth” and “reveal gender disparities in access to basic resources.”

with relative human femur length values.⁵ Hence, this indicator allows us to measure health of men and women over two millennia.

We find that women of the Scandinavian periphery already had relatively favorable health in both absolute and relative terms during the medieval period, compared with other European samples of the time. This might have inspired popular myths about women in Nordic countries: Valkyries were strong, healthy and tall in these myths. The source of these myths might be identified using our new measure for early gender equality.

We argue that a potential explanation for this early gender equality might be based on agricultural specialization in cattle farming, which provides a stronger role for women in generating substantial parts of the family income. This strengthens their position and implies gender equality – which could be culturally and institutionally transmitted even to societies after industrialization, in which agriculture is no longer important (Norling 2016). In other words, we add to the view of a long-term impact on gender equality proposed by Dilli et al. (2015), by adding a background variable which also leads to a very persistent influence, namely, the agricultural specialization in cattle farming. The origins of this specialization might be more geographic rather than institutional (although interactions with institutions were likely taking place), but the long-term influence was similar and was relatively independent of income, as Scandinavia was poor during the medieval period.

⁵ On related studies, see Koepke and Baten (2005), Komlos (1998), Steckel and Prince (2001), Steckel (2009), Steckel and Rose (2002).

Linear Enamel Hypoplasia as an indicator of malnutrition and disease

Before we discuss the gender equality indicator as a function of linear enamel hypoplasia ratios (henceforth, LEH), we firstly focus on the basic LEH indicator. What does LEH stand for? Are there any potential issues in measuring it? LEH indicates a permanent defect on teeth formed during the crown formation and resulting from developmental childhood stress, i.e., poor health and malnutrition (Goodman et al. 1991, Ortner 2003, Palubeckaitė et al. 2002, Steckel and Rose 2002).⁶ Teeth are permanently affected by diseases and especially by nutritional deprivation during early childhood (Scott et al. 1991). It typically occurs after the weaning phase, between the ages of 1.5 and 6 years (Bereczki et al. 2018).⁷ Human anthropologists classify it as a “non-specific” stress indicator because a variety of health issues can cause it (Bereczki et al. 2018). Almost all of these issues are related to nutrition that is protein deficient or insufficient in general, and to childhood disease. In accordance with the Global History of Health Project (henceforth, GHHP; see Steckel and Rose 2002), we limit the sample to permanent teeth (not deciduous).

⁶ For a review on the origins of the use of LEH within anthropological studies and categorization of the different types of developmental enamel defects, see Schultz et al. (2001). For a detailed explanation of LEH, see Steckel and Rose (2002, p. 22-27).

⁷ According to the definition provided in Lewis (2018, p. 84) in *Paleopathology of Children*, “dental enamel hypoplasia are areas of decreased enamel thickness that occur during a disturbance of ameloblast deposition on the developing crowns of permanent and deciduous teeth”. Factors such as malnutrition and disease interrupt the process, leading to an impaired matrix that becomes visible in the form of permanent lines or grooves on teeth (Arcini 1999, Steckel and Rose 2002). Hypomineralisation (MIH) is an important issue as well. However, it is more prevalent on molars, although it occurs on incisors as well. We follow the Steckel et al. (2018) definition in order to keep the results comparable: In the European History of Health data set and in our compilation of additional Scandinavian evidence, only studies on incisors and canines were considered.

Some issues should be discussed when using LEH evidence: (1) How should the LEH share be specified? I.e., should it only include severe cases (i.e. those with two or more lines)? (2) Does the osteological paradox bias the analysis? (3) Could social and (4) regional selectivity play a substantial role? (5) Does measurement error invalidate the results?

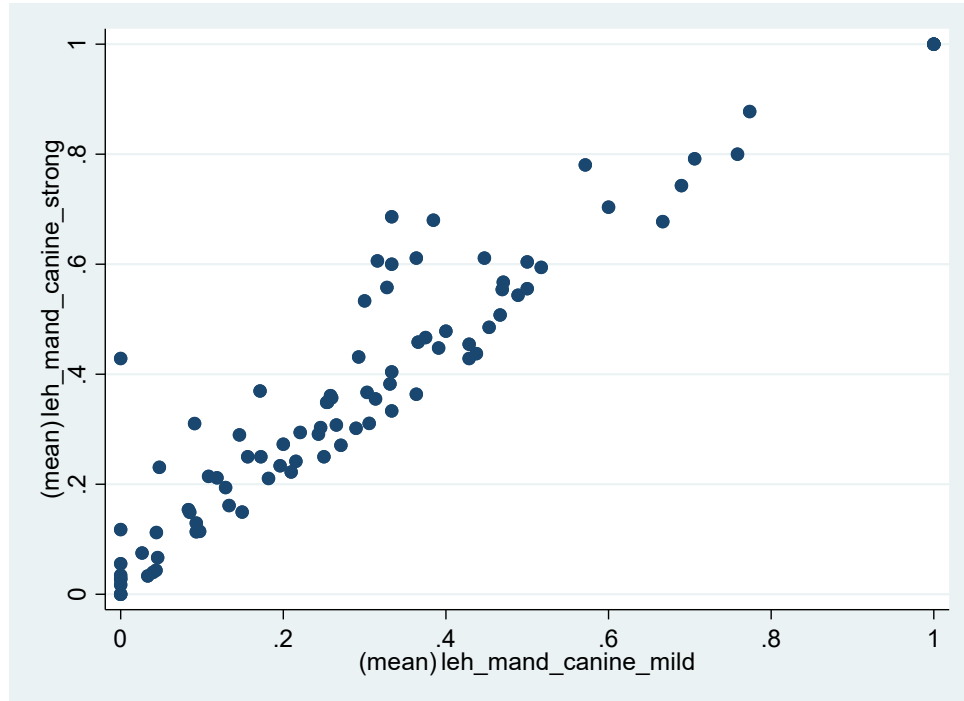
(1) One potential issue is the exact specification of LEH: should we only include very severe cases and contrast them with no hypoplasia, or should we contrast all forms of hypoplasia with the non-LEH cases? To measure the share of individuals affected by LEH, we follow the standard method used by numerous authors and calculate the proportion of individuals with “one or more” LEH lines (Kjellstrom et al. 2005, Steckel and Rose 2002, Zhou and Corruccini 1998, Goodman et al. 1987). To check the appropriateness of this strategy, we can also compare the evidence for using only severe LEH with “two or more lines” systematically, as opposed to the more comprehensive “one or more” hypoplasia line benchmark.⁸ The evidence from the European History of Health Project (EHHP from here, Steckel et al. 2018) provides both measurement options for 103 sites across Europe. We find correlations above 0.86 for all types of teeth (p -value < 0.001). If the observations are restricted to those with an underlying number of individuals above 30, then the correlation even increases to 0.93. In Figure #1 we illustrate that this is not driven by individual outlying observations.⁹ In conclusion, we recommend calculating the share of those skeletons with both mild and

⁸ Based on the data from the European History of Health Project, the examinations made to identify the grooves were macroscopic (felt with fingernail). Table A1 lists the sources from which we collected the LEH incidence share for the Northern countries that we added in this study.

⁹ Of course, the correlation is also strong because severe LEH is included in both specifications. However, the severe version accounts for only ca 1/3 of LEH among adults, see Bereczki et al. (2018).

severe LEH relative to all remains, because this is compatible with a vast amount of LEH studies that were already published.

Figure #1: Should the LEH share include mild and strong, or strong LEH only?



Source: EHHP. The figure reports canine data. Incisor figures look almost identical.

(2) The osteological paradox could play a role in our context as well: The osteological paradox hypothesis was first suggested by Wood et al. (2002), who questioned whether there was indeed a decline in health after the transition from hunter and gatherer societies to the farming economies of the Neolithic agricultural revolution, as argued by Cohen and Armelagos (1984). This view was based on relative health, indicated by lesions of bones. The idea of the osteological paradox was that sicker populations might look healthier in the skeleton data -- the reason being that very sick individuals may die quite early, and thus do not live long enough to manifest skeletal lesions. Hence the healthier population in which the children survive might look sicker, and vice versa. This is particularly plausible for bone lesions which are generated in a

cumulative way over the whole life cycle (such as nonlethal traumata or periostitis, for example). In contrast, LEH is formed during a short time window of early childhood and does not cumulate over the whole life cycle. Thus, the osteological paradox bias is less likely for LEH.¹⁰

(3) The EHHP used various strategies to minimize social selectivity (details in Baten and Steckel 2018). We also adopted these in our additional data collection. One of the methods we used to avoid social selectivity was to only include samples that covered total populations of villages and town quarters, rather than socially selective samples. For example, elite graves were not included. Only very few military and religious samples were included. In height studies on the 18th to 20th centuries that rely on archival records of volunteer armies and prison registers, labor market selectivity was sometimes hypothesized to influence the sample composition (Bodenhorn et al. 2017). This kind of selectivity does not occur in archaeological evidence, in which whole settlement populations were buried in their cemeteries.

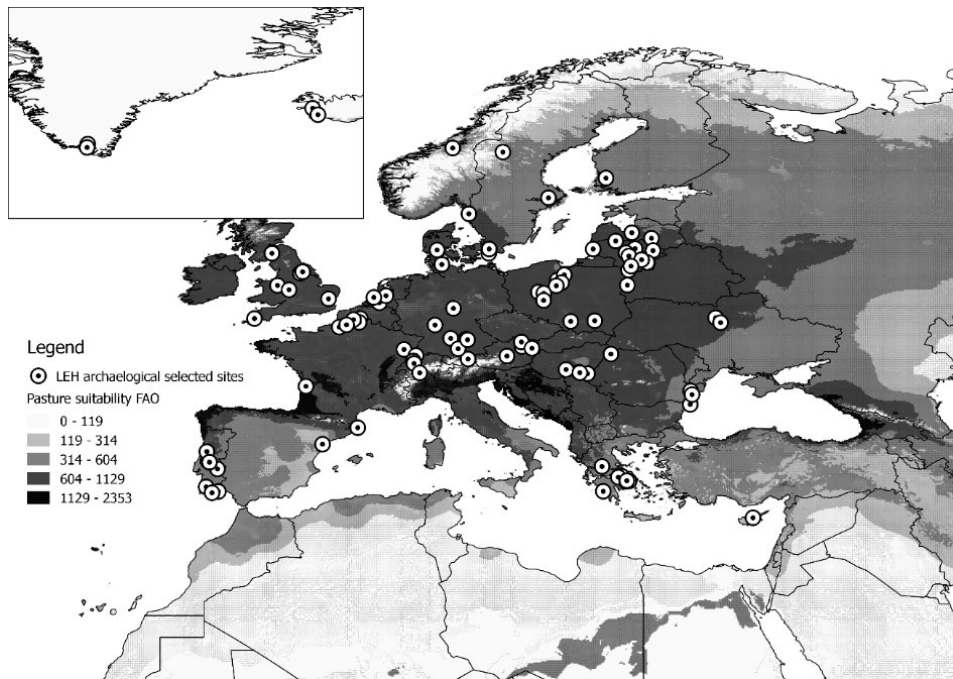
(4) Is regional selectivity a major issue? Our evidence comes from a variety of studies that provide evidence on LEH, based on archaeological evidence. Table #A1

¹⁰ There are a number of studies which have discussed this osteological paradox with mixed results (for example, Siek 2013). The paradox is attractive as a theoretical concept. However, many studies observe that higher social status individuals also look healthier when we consider indicators based on their bones, compared to lower status individuals where we would expect lower health due to lower intake of high-quality food (see Swärdstedt 1966, for example). Steckel and Rose (2002) performed a detailed analysis in their study about the osteology of the Western Hemisphere and compared the longevity of samples drawn from northern and southern American skeletal samples with these health signals. They found a positive correlation between life expectancy and health in general. There was a single study which can be interpreted as the exception that proved the rule, as it was based on a poor house on the east coast of the U.S. during the 19th century, in which some people from middle-class households might also have ended up, after impoverishment due to a variety of reasons.

displays the additional observations that we collected for the Nordic countries (see also Cairns 2015, p. 36), and Figure #2 shows the geographical distribution for all the sites included in the analysis.¹¹ A substantial amount of data was drawn from the EHHP (Steckel et al. 2018), as well as the Western Hemisphere project (Steckel and Rose 2002). The EHHP recorded observations from all major regions of Europe, and we added Scandinavian countries that were missing here. Our samples are broadly regionally representative for Europe, as becomes visible in Figure #2.

¹¹ According to Cairns (2015, p. 36), regarding nutritional values and childhood stress, only a few studies such as Scott et al. (1991), Yoder (2006) and Lieber-Harkott (2012b) have analyzed physiological disruptions to address environmental, social, and economic factors in Scandinavia. The author provides information on the European samples and clarifies which types of health and disease measurements are available for the corresponding samples.

Figure #2: Geographical distribution of our sample



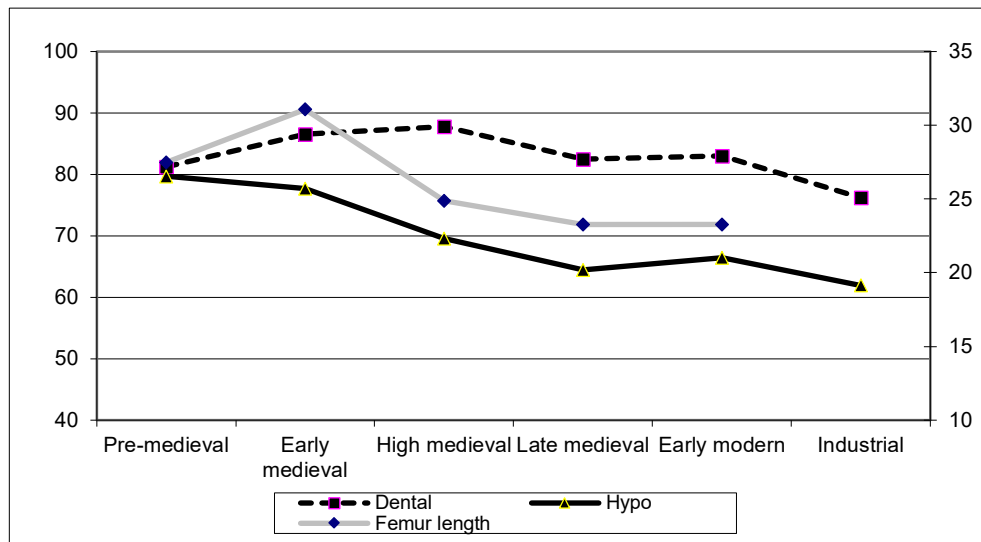
Source: Author's elaboration

(5) Archaeological evidence necessarily contains a vast amount of measurement error, even if only teeth and bones of sufficient preservation status are used. One strategy to assess potential measurement error of this indicator is to study the correlation between LEH prevalence and height levels. Over time, an extensive literature has collected evidence on adult stature of both males and females to measure biological standards of living (Koepke and Baten 2005, Komlos 1998, Steckel and Prince 2001, Steckel 2009, Steckel and Rose 2002).

We can gain relevant insights into the degree of measurement error if we compare the LEH observations with evidence on femur length. If both correlate through time and across samples, every indicator is less likely to be distorted by measurement error. To clarify this relationship, we compared the evidence of LEH, dental health and femur length for six periods of European history (see Figure #3, based on Baten et al. 2018). As all three indicators reflect an increasingly starchy diet (lack of protein) and

deteriorating disease environments after the early medieval period, the observed correlation of trends is as expected.

Figure #3: Trends in Health using Dental Health Index, Absence of Hypoplasia Index (both on left scale) and the Femur Length Index (right axis)



Sources: see Baten et al. 2018. The underlying data comes from the chapters in Steckel *et al.* 2018 on Dental Health, Hypoplasia and Femur Length in this volume, namely Wittwer-Backofen and Engel (2018), Meinzer et al. (2018), and Bereczki et al. (2018). These health trends are based on health index components as defined in Steckel and Kjellström's chapter in Steckel *et al.* 2018 on health index values.¹² All 101 sites are included. All the variables are scaled that higher values indicate better health, see the chapter on the Health Index Volume. The value of femur length during the industrial period (28.9) is not shown above, as it based almost exclusively on the UK and Swiss lengths, which had unusually high country-specific values and are therefore not representative. The other values are not affected by strong selectivity.

¹² The dental health index was calculated following the procedures discussed in Steckel *et al.* (2002), Steckel and Kjellström (2018), based on the data reported and analyzed by Wittwer-Backofen and Engel (2018). It is based on pre-mortem-tooth loss, cavities, and abscesses using the formulas: first, the completeness is $1 - (\text{pre-mortem loss} + \text{cavities}) / (\text{teeth} + \text{pre-mortem loss})$. Next, the overall dental score is weighted 75 percent from completeness and 25 percent from abscesses (defined as the share of individuals without an abscess).

Bereczki et al. (2018) also compared height and LEH documented in skeletons of Native Americans over the last two millennia, from evidence recorded in the Western Hemisphere module of the GHHP (Steckel and Rose 2002). They used a LEH absence index in the analysis, which was defined as the inverse of the raw LEH rates. For this study, Bereczki et al. used the dataset “Ecological Variable: 65 Sites” from the Western Hemisphere module of the GHHP website and added the LEH index values from Steckel and Rose (2002). They only included observations on Native Americans. The result was a modest but significant correlation between LEH and femur length (correlation coefficient 0.40, $p=0.06$, see Bereczki et al. 2018).

In sum, the LEH indicator is an important and relatively unbiased indicator of health and nutrition during childhood. For Europe, social and regional representativeness is broadly given, although clearly not perfect. The correlations between LEH and other indicators of health and nutrition suggest that measurement error does not invalidate the results.

The LEH ratio as an indicator of gender equality

Guatelli-Steinberg and Lukacs (1999) discussed whether LEH ratios capture sex-biased preferential treatment during childhood. Can higher LEH values for women than for men indicate son preference? Guatelli-Steinberg and Lukacs discussed several local samples, while they did not perform a systematic statistical analysis to analyze all samples together (see also Cairns 2015, p. 189).¹³ We are performing such a study for

¹³ Most anthropological and clinical studies have not focused on gender differences when analyzing the prevalence of LEH (except for Guatelli-Steinberg and Lukacs, 1999). In their review, Guatelli-Steinberg and Lukacs (1999) explain that, before the 1990s, only a few articles addressed sex differences, such as Swärdstedt (1966), for medieval Sweden, and Goodman et al. (1976), for Prehistoric Native Americans. In 1978, Najjar et al. studied sex differences for

the first time, which is one component of the value-added by our study. Data contained in a large number of studies are compatible with the view that a higher frequency of LEH on females compared to that of males is caused by male preferential treatment in access to essential resources during childhood, and most authors tend to interpret their data in this way (Goodman et al. 1987, Oyamada et al. 2012, Irei et al. 2008, Låås and Kjellström, forthcoming). An extreme case is discussed by Oyamada et al. (2012) and Irei et al. (2008), who find that the frequency of LEH in Japan's Early Modern Period was higher among females than among males, resulting from higher physiological stress due to the adverse treatment of girls.

One potential issue is the hypothesis of “female buffering.” Female bodies are more adept to surviving during famine or other catastrophes (and rapid repopulation). Hence, biologists hypothesized that female bodies might be more resilient. Guatelli-Steinberg and Lukacs (1999, p. 80-87) also review the studies about “female buffering” and other biological factors that vary intrinsically with sex and can be confused with preferential treatment.¹⁴ However, some studies raised doubts about the relevance of

individual skeletons and living individuals in Cleveland and, in 1980, Goodman et al. provided a sex-based analysis of LEH for a sample collected in Dickson Mound for the period between 950 and 1300 CE. Years later, Larsen (1995) took sex differences into consideration when analysing biological changes like transitions to agricultural societies. To our knowledge, Cairns (2015) is the first author to undertake an aggregate analysis for different countries (from 10 sites within these countries) of various dental health indicators and relate them to environmental features. Hanson and Miller (1997) compare LEH for females and males in three Scandinavian countries.

¹⁴ In addition, other factors that might vary intrinsically with sex (e.g., sex chromosomes). In addition, Suckling et al. (1987), Goodman, and Rose (1990) argued that LEH could also result from hereditary anomalies, localized trauma, and metabolic stress. However, the evidence on individuals with hereditary LEH anomalies is low and less probable in prehistoric populations; indeed, the authors cite only one case of hereditary enamel hypoplasia from a prehistoric skeleton (Goodman and Rose 1990, p. 64).

female buffering: A high level of malnutrition and adverse disease environment existed almost permanently during the period before the 20th century (Koepke and Baten 2005). It is not clear whether a more-than-normal level of deprivation increases the female buffering effect disproportionately. A number of studies reject this (for example, Guntupalli and Baten 2009). Certainly, the female buffering hypothesis implies that any calculation of relative LEH prevalence between males and females needs to take into account that equal shares of LEH among females already indicate an unequal distribution of resources. In other words, equal LEH values indicate more adverse behavior towards young girls than towards boys, because buffering reduces the strength of LEH signals for girls. Such a linear effect does not affect our analysis in a problematic way. In a similar vein, Guatelli-Steinberg and Lukacs (1999, p. 118) conclude that any distorting effects (beyond the normal level effect) are probably minimal. They examine the adaptability of females based on certain group characteristics (such as socio-economic status). They find limited evidence on the presence of intrinsic sex differences in the composition of enamel that can affect the expression of LEH and obtain insignificant support for female buffering. Guatelli-Steinberg and Lukacs conclude that sex differences in the incidence of LEH are a good “biological marker of preferential investment in sons” and capture more accurately the effect of access to essential resources rather than the presence of female buffering or male vulnerability.

We also find this when we compare relative heights and relative LEH values below. The symmetry of both ratios indicates that nonlinear aspects of buffering are not a major problem.

Storey (1998, p. 134-135) similarly argues that LEH differences (together with other stress indicator differences like those of porotic hyperostosis, cribra orbitalia, and

adult stature) can indicate whether “one sex received a better diet and a buffered, healthier, or more hygienic environment” and, therefore, “the presence of paleopathological conditions in adult skeletons, in combination with other cultural information, can be used to infer son preference or daughter neglect.”

Stini (1985), Storey (1998) and Guntupalli and Baten (2009) have argued that sex differences in stature are evidence of gender-specific inequality in access to basic resources.¹⁵ Crucial for our methodological approach is the question of whether relative LEH values are informative for gender inequality. We have studied the relatively homogeneously recorded EHHP dataset on skeletons in Europe (Steckel et al. 2018). We find a robust correlation between gender equality measured with relative femur length and gender equality measured with relative hypoplasia prevalence. The former is defined as the ratio between the average femur length of females over that of males per site (*flen_eq*). The latter is the ratio between the average share of LEH of males over females (*leh_eq*). A correlation coefficient is positive and statistically significant (0.46; $n=46$; $p=0.001$). It indicates that a higher femur length for females relative to that of males correlates with a lower relative incidence of LEH in females. In Figure #4, we see that no outliers drive this correlation.¹⁶ The relationship is rather based on the whole sample, even if there is some noise around the regression line. We conclude that the differences in the LEH values between men and women are most probably an informative indicator of gender inequality if the samples are not too small. Nonlinear biases from female buffering seem not to invalidate it.

¹⁵ Namely, in the case of Europe during the first millennium CE, individual heights were negatively affected by gender inequality (Koepke and Baten 2005).

¹⁶ For the Western Hemisphere, the observations are too low ($n=15$). In addition, a regression controlling for Europe and period dummies for every 500 years also displays a positive and significant coefficient at a 1 percent confidence level.

Like many economic and social indicators, LEH is a bounded variable, and cannot move below 0 percent or above 100 percent. This implies that in extremely dire circumstances if both genders were so extremely unhealthy that they would reach 100 percent LEH, the ratio would not reflect gender inequality any longer. Similarly, if general health is perfect and LEH is 0 for both genders, smaller differences in gender discriminative behavior might still exist (in other areas than basic health), but would not be visible in our LEH variable. This is like relative literacy rates of males and females that also lose their indicator function if both genders had either 0 or 100 percent (and this would similarly apply to other bounded variables). Fortunately, we observe no observations in which both the LEH rates for males and females are 0 percent, and only 2.1 percent of observations in which both are 100 percent for the study period of the last two millennia, even less for the early and high Middle Ages, and none for our Scandinavian sample. Hence we can conclude that bounded variable issues are not likely during this period for relative LEH values.

12th and 17th centuries.¹⁷ She provides a detailed breakdown of LEH by type of tooth and sex, and compares the overall results to other sites in Europe. The results show that the frequency of LEH was significantly higher for males in most cases.¹⁸ Similarly, Swärdstedt's study (1966), based on Gejvall (1960), examined skeletal material in Jämtland (Sweden) between 1025 and 1375 CE by age-group, social category, and period.¹⁹ The results display a higher incidence of LEH among males (particularly at the ages of 1.5, 3, and 3.5) and the LEH incidence was almost always higher for males for all etiological ages (between 0 and 16).²⁰ Consistently, for the case of Haffjarðarey (and based on a sample dated between approximately 1200 and 1563), Gestsdóttir (2004) finds that the number of male individuals with LEH was higher, but the author does not provide any explanation regarding this difference.

Ultimately, Palubeckaitė et al. (2002) compare three different populations (rural, urban, and aristocracy) from Danish and Lithuanian late medieval and early modern samples to identify the causes of the prevalence of LEH and its potential effect on longevity.²¹ For the Danish rural sample in Tirup, the author finds that the incidence of LEH was higher (although insignificant) for males. In the case of Finland (the site of Luistari), Salo (2005) analyses teeth from individuals buried between 600 and 1130 and shows that LEH was three times more common in males. The author argues that this

¹⁷ Based on Göthberg (1986), her study is divided in different phases: Phase 1 (12th century), Phase 2 (12th-13th century), and Phase 3 (13th to 17th centuries).

¹⁸ There are some exceptions, particularly when the data is disaggregated and observations are too low; see Cairns (2015) for details.

¹⁹ Social groups were divided into *länder*-men, holder-men, and slaves. The periods were classified into 1025-1150, 1100-1225, 1175-1300, and 1250-1375. Both categorizations are based on Gejvall (1960).

²⁰ He calculates the incidence of LEH by dividing the frequency of individuals with enamel hypoplasia and the individuals at risk. For more detail, see Swärdstedt (1966, p. 90).

²¹ Liebe-Harkort (2012) provides evidence for the Iron Age (0-260 CE) in Sweden (Smörkullen).

could also have resulted from the relatively better female conditions regarding nutrition and health or higher mortality of females from conditions related to hypoplasia.

Other authors have failed to find statistical significance of the sex differences in the incidence of LEH (Goodman et al. 1980, Lanphear 1990, Duray 1996, Malville 1997, Arcini 1999, Hanson and Miller 1997, see also the review from Palubeckaité et al. 2002). For instance, Scott et al. (1991) find that the incidence of LEH was similar for males and females in five Norse settlements dated approximately between the 11th and the 16th century (we define Norse as all Scandinavian settlements during this period).²² To complement Scott et al. (1991), Lynnerup (1998) examines skeletal material from Greenland, dated approximately from 950 to 1450 CE, and undertakes a different methodology to capture childhood stress. Based on fragmentary skull evidence from Thjodhilde's Church and Sandnes, he examines the frequency of infectious middle ear disease (IMED) among 83 adult individuals. Although the results are not significant, the incidence is slightly lower for females, on average. Arcini (1999) gives evidence of enamel hypoplasia in adults and adolescents by sex for Medieval Lund (Sweden) between 990 and 1536 CE. Although she finds significant differences in trends over time (the incidence was lowest in the earlier period), the sex disparities were insignificant. Similarly, Boldsen (1998) studies Tirup (in Denmark) during the 12th century and argues that, although the frequency of episodes was a "little higher" among females, it is not statistically significant.²³ Finally, Zöega and Murphy (2016) analyze

²² They also find that the three Greenland samples, which were similar to each other, displayed lower LEH frequencies in comparison to those for medieval Norway and Iceland. In fact, Norway had extremely high LEH incidence values.

²³ Yoder (2006) notes that in Denmark between the 12th and 16th century the sex differences for alternative paleopathological indicators capturing childhood dietary deficiencies (such as cribra orbitalia and porotic hyperostosis) are mostly insignificant except for the significantly higher female porotic hyperostosis values in the total and peasant sample.

several health indicators obtained from skeletons that belonged to a cemetery on a farm that experienced the transition from the Late Viking Age to the Early Christian era in Skagafjörður, the Northern part of Iceland. They find that sex differences are insignificant for all pathologies analyzed and argued that the high LEH incidence comes from very harsh living conditions (Zöega and Murphy 2016; p. 582).

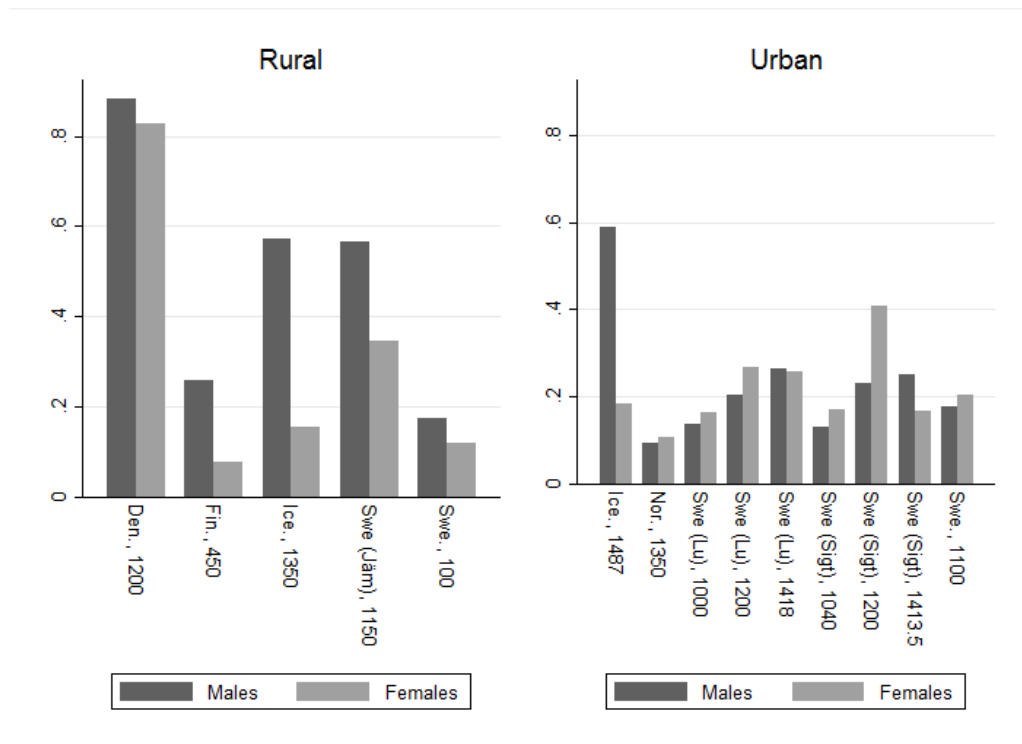
However, a few studies have indicated that the LEH incidence was higher in females. In Sigtuna, an urban settlement in Sweden, Kjellström et al. (2005) study a total of 528 skeletons distributed across churchyards and burials through three different phases between 980 and the Swedish Reformation period (approx. 1500).²⁴ They conclude that, in general, children in Sigtuna underwent rough living conditions and, based on heights and LEH evidence, they argue that females suffered higher levels of childhood stress. Nevertheless, the incidence of stress increased in general (but more for females) during the three phases because of worse living conditions due to the urbanization and higher population density in Sigtuna.

Taking all these Norse observations together we find that, in any rural site that has been excavated in Scandinavia and was analyzed through enamel hypoplasia, the prevalence was lower for women compared to that of men (Figure #5).²⁵ The differences are especially large in Finland and Iceland. In urban Scandinavia, in contrast, the results are more mixed. In the slightly larger cities such as Lund, Sigtuna, and Trondheim, females are often slightly disadvantaged; whereas in a small town in Iceland we observe a pattern of relatively good health and nutrition among women, relative to the incidence among men.

²⁴ The period between 900 and 1100 is regarded as the transition period from Viking Age to Middle Ages.

²⁵ This sample excludes the observations provided by Richard Scott. If the latter are included, only Greenland in 1050 stands as an exception.

Figure #5: LEH of males and females in Northern Europe



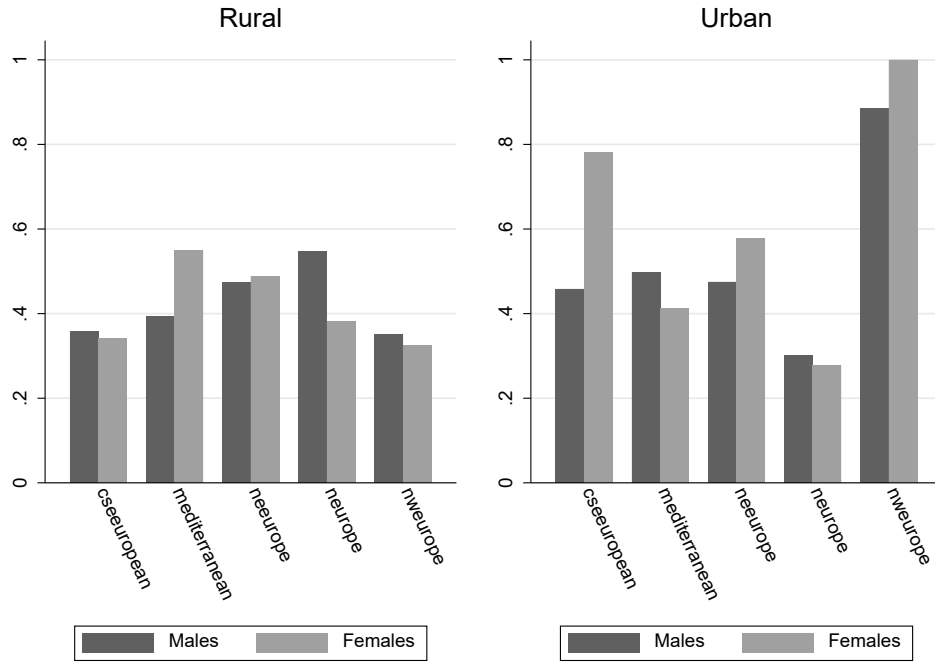
Comparing these Scandinavian patterns with those in other European countries, we find that Scandinavia is the only region with a significantly lower incidence of LEH among females in rural areas, compared to males, indicating a comparatively strong rural health status for women (Figure #6, descriptive breakdown of the number of observations by region in Table A2 in the Appendix). In the Mediterranean regions, rural women are strongly disadvantaged. In other rural regions of Europe, the situation is more balanced. In urban areas, hypoplasia values in absolute terms were generally lower for Northern Europe, and the gap between females and males is comparatively small. In North-Eastern, Central, South-Eastern and North-Western Europe females were more disadvantaged. In sum, in urban Northern Europe (and in the urban Mediterranean), the sex differences in LEH rates were slightly lower, suggesting a marginally more favorable situation for girls than in urban Northeast, Southeastern and Northwestern Europe.

In Table #2, we assess, in various specifications of different (overlapping) periods, that the Norse countries are significantly different from the rest of Europe. This is true if we drop the large urban areas and focus on the rural Scandinavian periphery. For instance, as shown in second column in Table #2, once we drop the large urban areas, we obtain coefficients between 0.72 and 0.81 on columns (2) to (5), which is quite substantial in its economic implication.²⁶ As visible in Figure #4, the male/female LEH share ratio ranges from 0 to 3, but most of the values range from 0.8 to 2. The constant in Table #2, between 1.07 and 1.36 reflects the gender equality outside of rural Scandinavia. Hence, a difference between the Scandinavian periphery and the other regions of Europe of 0.72-0.81 is quite substantial. Furthermore, if we look at the female incidence of LEH in absolute terms and run the same regression (see Table #3), we can see that, although the explanatory power is low, women in the Norse countries fared better than women in other European regions.

In this Table, we use various periods in order to assess the robustness of our results. We define the periods based on the end of the Roman Empire (ca. 450 CE, i.e. between the decisive dates of 410 CE and 476 CE), and on the change from the medieval to the early modern period (ca. 1500 CE). Admittedly, this periodization can be debated, but other thresholds yield similar results.

Figure #6: LEH of males and females in European regions

²⁶ The results are similar even if we control for regional effects. For example, if we include an additional control for the Central and South-Eastern Europe region (due to the significantly worse performance of females relative to males as shown in Figure 6), the coefficients gain significance for all the time periods analyzed and become larger in size. Furthermore, despite the small size of our sample, if we include regional fixed effects for all regions, it is still visible that the relative gender equality for Norse countries was higher and significantly different (results available from the authors).



Note: “cseeuropean” is “Central and South-Eastern Europe”; “Mediterranean” is “Mediterranean”; “neeurope” is “North-Eastern Europe”; “nweurope” is “North-Western Europe”; “neurope” is “Northern Europe”.

Table #2: Scandinavian gender equality was higher during the Middle Ages

VARIABLES	(1) LEHmal/LEHfem (450-present)	(2) LEHmal/LEHfem (450-1500)	(3) LEHmal/LEHfem (0-present)	(4) LEHmal/LEHfem (0-1500)	(5) LEHmal/LEHfem (0-present)
NEur	0.39 (0.11)	0.81** (0.04)	0.78** (0.02)	0.72** (0.04)	0.72** (0.03)
Constant	1.07*** (0.00)	1.12*** (0.00)	1.11*** (0.00)	1.36*** (0.00)	1.36*** (0.00)
Observations	89	47	95	61	95
R-squared	0.07	0.19	0.15	0.17	0.19
TimeFE	No	No	No	Yes	Yes
Drop	-	Sigt&Lund&Nor	Sigt&Lund&Nor	Sigt&Lund&Nor	Sigt&Lund&Nor

Robust p-values in parentheses; *** p<0.01, ** p<0.05, * p<0.1; The Norse (“NEur”) variable includes Denmark, Finland, Greenland, Iceland, Norway, and Sweden; Time fixed effects are included in column (4) and (5). Descriptives on the dependent variable (=the ratio of male LEH share to female LEH share) are reported in Table A3 in the Appendix.

Table #3: Less LEH incidence among females in Scandinavian than among other European females during the Middle Ages

	(1) LEHfem_share	(2) LEHfem_share	(3) LEHfem_share	(4) LEHfem_share	(5) LEHfem_share
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VARIABLES	(450-present)	(450-1500)	(0-present)	(0-1500)	(0-present)
Norse	-0.16** (0.02)	-0.10 (0.29)	-0.15* (0.07)	-0.18* (0.07)	-0.18* (0.07)
Constant	0.49*** (0.00)	0.47*** (0.00)	0.49*** (0.00)	0.46*** (0.00)	0.46*** (0.00)
Observations	97	54	103	68	103
R-squared	0.05	0.02	0.02	0.08	0.08
TimeFE	No	No	No	Yes	Yes
Drop	-	Sigt&Lund&Nor	Sigt&Lund&Nor	Sigt&Lund&Nor	Sigt&Lund&Nor

Robust pval in parentheses; *** p<0.01, ** p<0.05, *p<0.1; The Norse ("NEur") variable includes Denmark, Finland, Greenland, Iceland, Norway, and Sweden; Time fixed effects are included in column (4) and (5).

Is it plausible that lower gender inequality existed in Scandinavia in such an early period? Additional evidence comes from qualitative sources. As an illustration, by drawing on the concept of female autonomy, Yoder (2006) reports numerous studies highlighting the greater independence and equality of women in Scandinavia and Medieval Denmark in contrast to other European countries. Sawyer and Sawyer (1993) describe the role of women within the family structure and their place within inheritance rules. Based on research on Scandinavian laws,²⁷ they argue that the evidence points towards a bilateral kinship system within inheritance rules and birthrights; that is, no evidence supports the existence of a patrilineal society in Scandinavia.²⁸ Archaeological

²⁷ The authors base their analysis on Sjöholm (1978) and Winberg (1985).

²⁸ According to Sawyer and Sawyer (1993, p. 178-179), although there were regional differences, the "inheritance kinship was traced through both sexes and they [medieval rules] recognized that women have a right, if limited, to inherit." This was also the case for birth rights, which recognized bilateral kinship. For example, if females were closer in succession, they were able to reacquire the land that had been previously sold by their relatives. The authors also review qualitative evidence from runestones for the Early Middle Ages. The latter points towards the presence of bilateral kinship; however, it is difficult to recognize which runestones were affected by the influence of the church. Yoder (2006) - based on Bennett (1987), Jewell (1996), Sawyer and Sawyer (1993), Hanson 1992, Orrman 2003 - also reports that, in Scandinavia, females could even be entitled to half of their brother's lot and widows could receive a part of their husband's

findings from graves dated between the third/fourth and tenth/eleventh century in Denmark and Scandinavia show that females comprised many of the wealthiest burials and gained respect with age (Sawyer and Sawyer 1993, p. 206).²⁹ Accordingly, Roesdahl (1998, p. 64) explains that Norse women were better positioned regarding cultural norms than in other regions. For instance, based on reports by Arab emissaries who visited Viking sites, women were relatively free in their marriages and had the right to divorce. Concerning hereditary norms, on some occasions they even had the right to inherit land after the death of their children and parents.³⁰

These differences are also visible in the present state of Scandinavian gender equality. Countries like Iceland, Norway, Sweden, and Finland show the highest figures regarding gender equality, while countries such as Italy, Cyprus and Malta are cited as those with the lowest scores in Western Europe.³¹

Finland was the first country to elect a woman to parliament in 1907 and Scandinavian countries have displayed steady increases in female representation since, reaching 30 percent in the 2000s (Carmichael et al. 2014). The United Nations Development Program (2004, p. 221) states that Norway, Sweden, Denmark, and Finland display the highest gender empowerment figures (i.e. an index that includes variables such as the share of parliamentary seats held by women and the share of professional technical female workers) (Andersson et al. 2006; p, 255).

property (which was equal to the son's share). They could also enjoy the same right to divorce as men, could continue their husband's businesses after their death and, if unmarried, they could move to urban towns and own property.

²⁹ The authors rely on Sellevold (1989a) and Sellevold (1989b).

³⁰ Most of the evidence for the Viking-Age and earlier periods comes from written sources (such as laws), and those after Christianization were probably biased.

³¹ Data obtained from the Global Gender Gap Report 2017 by the World Economic Forum; see <http://reports.weforum.org/global-gender-gap-report-2017/>. Nake et al. (undated).

What could have explained the early gender equality in Scandinavia versus other regions?

Did the agricultural specialization in dairy farming improve the relative position of Scandinavian women? One potential explanation for the persistent gender equality in the Scandinavian periphery might come from gender-specific contributions to household income in cattle farming versus grain-based agriculture.

Gender roles and their persistence through time were repeatedly assessed for developing countries (Alesina et al. 2013, Boserup 1970, Carranza 2014, Hrdy 1990, Hansen et al. 2015, Iversen and Rosenbluth 2010). Agricultural specialization on cattle farming was chosen in high land-to-labor ratio areas with a sparse population (Boserup 1965). It affected the division of labor in favor of women (Alesina et al. 2013, Boserup 1970, Giuliano 2015). Grain agriculture with heavier plows gave men and their upper body strength a comparative advantage and pushed women to spend more time in the house.³² Thus, as Boserup (1970) explains, higher equality in gender roles was more common in economies with low population densities, long-fallow systems (usually smaller plots) and large-scale grazing.³³

³² This is demonstrated by Alesina et al. (2013, p. 469), who argue that the historical origins of gender division of labor can be explained using ploughs as these determined the “evolution of gender norms.”

³³ The higher fertility levels associated with agricultural societies and the time required for food-preparation in grain-based diets also decreased female labor participation as these activities demanded more time away from household chores (Hansen et al. 2015). The argument over the intensity of agriculture and the origins of gender roles is also found in anthropological and sociobiological studies. For instance, Hrdy (1990), based on Whyte (1978) and Schlegel and Barry (1986), stated that “where wives and daughters tend to make the greatest contributions to subsistence – in the gathering- and horticultural-based economies – women are more highly valued.”

The rural Norse samples analyzed in this study reflect societies that strongly relied on cattle farming and extensive grazing. For instance, Sawyer and Sawyer (1993, p. 59-60) describe the ample space devoted to cattle found in Danish farms during the ninth century. The authors argue that it was probably used to produce, sell, and export dairy products in the market.

Furthermore, the urban observations mirror the agricultural transition experienced during the Viking Age. Before the eleventh century, the share of the area of grain fields was extremely low. During the High Middle Ages, the transition to grain agriculture began around modestly growing urban centres and went together with population growth (Sawyer and Sawyer 1993, p. 48-49). Indeed, the urban samples shown in Figure #5 which display a higher LEH female incidence – i.e. Lund (Sweden), and Sigtuna (Sweden), and to a lesser extent Trondheim (Norway) – are located in the regions more specialized in cereal cultivation (that is, the southern regions of Sweden such as Skåne and the Mälaren valley, and around Trondheim in Norway) (Sawyer and Sawyer 1993, p. 48).³⁴

Therefore, based on the literature about the origins of gender roles we suggest that modes of production and changes in agricultural practices played a significant role. Hence, to explain past regional differences in gender disparities, it is necessary to identify the environmental features that determined the type of agriculture. Although different theories have been proposed to explain preferential sex bias (some focusing on cultural determinants and others on biological ones), there is a growing consensus that

³⁴ Sawyer and Sawyer (1993) mention also the Mälaren lake. The only observation we have for that area is Sigtuna, but additional preliminary results in Låås and Kjellström (forthcoming) argue that the frequency of LEH on females is higher and potentially caused by male preferential treatment in the access to essential basic resources during childhood.

local ecological conditions strongly determine the decisions regarding preferential treatment (reviewed by Hrdy 1990).³⁵

Conclusion

This study suggests a new indicator for gender equality that enables us to trace gender equality over millennia of human history: relative linear enamel hypoplasia (LEH) values allow us to identify the relative health and nutritional status of boys and girls in the past. Using a new sample of Scandinavian and other European skeletal remains, we carefully assessed whether issues such as (1) the specification of LEH, (2) the osteological paradox, (3) social selectivity, (4) regional selectivity, (5) measurement error and (6) female buffering might potentially invalidate the results. We found that this was not the case, although a certain amount of measurement error cannot be avoided using skeletal remains for health analysis.

We find that females in the rural periphery of Nordic countries during the Viking period and the later Middle Ages had relatively high status, resulting in substantial nutritional and health resources being allocated to girls (not only to boys, if both were competing for them). Female equality was remarkable in rural Scandinavia, especially in comparison to other European regions which had a stronger preference for boys during the Early Middle Ages.

This also contributes substantially to the modern literature on gender equality, particularly that which includes historical factors that do change rapidly over the centuries, such as Dilli et al.'s (2015) family and religious institutions.

²⁹ According to the author, these can be either reproductive (marriage options) or economic (subsistence conditions).

Our evidence on relative LEH suggests that the modern gender equality values that can be observed for Scandinavia have precedence in the lower gender differences which were set in the period between 500 and 1500 CE. In popular myths about Nordic countries, Valkyries were strong, healthy and tall. The source of these myths might be identified using our new measure for early gender equality: relative LEH values.

References

1. Alesina, A., Giuliano, P., and Nunn, N. (2013). "On the origins of gender roles: Women and the plough". *The Quarterly Journal of Economics*, 128(2), 469-530.
2. Andersson, G., Hank, K., Rønsen, M., and Vikat, A. (2006). "Gendering family composition: Sex preferences for children and childbearing behavior in the Nordic countries". *Demography*, 43(2), 255-267.
3. Arcini, C. (1999). *Health and Disease in Early Lund: Osteo-Pathologic Studies of 3.305 Individuals Buried in the First Cemetery Area of Lund 990-1536* (doctoral dissertation), Lund University, Sweden: Department of Community Health Sciences, Medical Faculty.
4. Baten, J., and Steckel, R.H. (2018) "The History of Violence over the Past Two Millennia: Archaeological Bone Traumata as a Source for European Violence History", in Richard Steckel et al., *The Backbone of Europe: Health, Diet, Work and Violence over Two Millennia* (Cambridge et al.: Cambridge University Press, 2018).
5. Baten, J., Steckel, R., Spencer Larsen, C., and Roberts, C. (2018). "Multidimensional Patterns of European Health, Work, and Violence over the Past Two Millennia" in Steckel, R.H., Roberts, C. Larsen, C.S. and Baten, J., "*The Backbone of Europe: Health, Diet, Work and Violence over Two Millennia* (Cambridge et al.: Cambridge University Press, 2018).
6. Bennett, J. M. (1987). *Women in the medieval English countryside: gender and household in Brigstock before the plague*. Oxford University Press.
7. Bereczki, Z., Teschler-Nicola, M., Marcsik, A., Meinzer, N. J. and Baten, J. (2018). "Growth disruption in children: Linear enamel hypoplasias", in Steckel, R. et al., *The Backbone of Europe: Health, Diet, Work and Violence over Two Millennia*, Cambridge et al.: Cambridge University Press.
8. Bodenhorn, H., Guinnane, T. W., and Mroz, T. A. (2017) "Sample-Selection Biases and the Industrialization Puzzle." *Journal of Economic History*, 77 (1): 171–207.
9. Boldsen, J. L. (1998). "Body proportions in a medieval village population: effects of early childhood episodes of ill health". *Annals of human biology*, 25(4), 309-317.
10. Bolt, J., and Van Zanden, J. L. (2014). "The Maddison Project: collaborative research on historical national accounts". *The Economic History Review*, 67(3), 627-651.

11. Boserup, E. (1970). *Women's role in development*. London: Earthscan.
12. Boserup, E. (1965). *The Conditions of Agricultural Growth: The Economics of Agrarian Change under Population Pressure*. London, G. Allen and Unwin, Chicago: Aldine, 1965.
13. Boserup, E. (2017). *The conditions of agricultural growth: The economics of agrarian change under population pressure*. Routledge
14. Cairns, A. M. (2015). *Health in medieval and early modern Norway: a comparative analysis of the impact of social, economic and environmental change on skeletal remains*. Ph.D. thesis: Australian National University.
15. Carmichael, S., Dilli, S., and Rijpma, A. (2014). "Gender inequality since 1820" in Van Zanden, J. L., et al. (2014). *How was life?: Global well-being since 1820*. OECD publishing.
16. Carmichael, S., Dilli, S., and Rijpma, A. (2016). "Women in Global Economic History", in: Baten, J. (Ed.). (2016). *A History of the Global Economy*. Cambridge University Press, pp. 240-47.
17. Carmichael, S., De Pleijt, A., Van Zanden, J., and De Moor, T. (2016). "The European Marriage Pattern and Its Measurement". *The Journal of Economic History*, 76(1), 196-204. doi:10.1017/S0022050716000474
18. Carranza, E. (2014). "Soil endowments, female labor force participation, and the demographic deficit of women in India". *American Economic Journal: Applied Economics*, 6(4), 197-225.
19. Cohen, M. N. and Armelagos, G. J. (Eds.). (1984). *Paleopathology at the Origins of Agriculture*, New York: Academic Press. Reprinted, 2013, University Press of Florida, Gainesville.
20. De Moor, T., and Van Zanden, J. L. (2010). "Girl power: The European marriage pattern and labour markets in the North Sea region in the late medieval and early modern period". *The Economic History Review*, 63(1), 1-33.
21. Dennison, T., and Ogilvie, S. (2014). "Does the European marriage pattern explain economic growth?" *The Journal of Economic History* 74(3), 651-93.
22. Dennison, T., and Ogilvie, S. (2016). "Institutions, Demography and Economic Growth". *The Journal of Economic History* 76(1), 205-17.

23. Carmichael, S. G., de Pleijt, A., Van Zanden, J. L., and De Moor, T. (2016). “The European marriage pattern and its measurement”. *The Journal of Economic History*, 76(1), 196-204.
24. Dilli, S., Rijpma, A., and Carmichael, S. G. (2015). “Achieving gender equality: Development versus historical legacies”. *CESifo Economic Studies*, 61(1), 301-334.
25. Dollar, D., R. Fisman and R. Gatti (2001), “Are Women Really the ‘fairer’ sex? Corruption and Women in Government”, *Journal of Economic Behavior and Organization* 46, 423–9.
26. Duflo, E. (2003). Grandmothers and granddaughters: old-age pensions and intrahousehold allocation in South Africa. *The World Bank Economic Review*, 17(1), 1-25.
27. Duflo, E. (2012). Women Empowerment and Economic Development. *Journal of Economic Literature*, 50 (4). 1051-79.
28. Duray, S. M. (1996). “Dental indicators of stress and reduced age at death in prehistoric Native Americans”. *American Journal of Physical Anthropology: The Official Publication of the American Association of Physical Anthropologists*, 99(2), 275-286.
29. Gejvall, N. G. (1960). *Westerhus: medieval population and church in the light of skeletal remains* (Vol. 43). H. Ohlssons boktr.
30. Gestsdóttir, H. (2004). “The palaeopathology of Iceland: preliminary report 2003: Haffjarðarey, Neðranes & Viðey” (WP FS225-99192). Fornleifastofnun Íslands: Reykjavík.
31. Giuliano, P. (2015). “The role of women in society: from preindustrial to modern times”. *CESifo Economic Studies*, 61(1), 33-52.
32. Goldstein, M., Hounghbedji, K., Kondylis, F., O’Sullivan, M., Selod, H. (2015). Formalizing Rural Land Rights in West Africa Early Evidence from a Randomized Impact Evaluation in Benin. World Bank Policy Research Working Paper 7435.
33. Göthberg, H. (1986). Kyrkogarden på Folkebibliotekstomten i Trondheim. Fasindelning. In: T. Anderson and H. Göthberg, editors. Olavskirkens Kirkegård: humanosteologisk analyse og faseinndeling, Trondheim, Riksantikvaren: Utgravningskontoret for Trondheim: 17-36.

34. Goodman, A. H. (1976). "Enamel hypoplasia as an indicator of stress in three skeletal populations from Illinois" (Abst.). *American Journal of Physical Anthropology*, 44, 181.
35. Goodman, A. H., Allen, L. H., Hernandez, G. P., Amador, A., Arriola, L. V., Chavez, A., & Pelto, G. H. (1987). "Prevalence and age at development of enamel hypoplasias in Mexican children". *American Journal of Physical Anthropology*, 72(1), 7-19.
36. Goodman, A. H., Armelagos, G. J., and Rose, J. C. (1980). "Enamel hypoplasias as indicators of stress in three prehistoric populations from Illinois". *Human biology*, 515-528.
37. Goodman, A. H., Allen, L. H., Hernandez, G. P., Amador, A., Arriola, L. V., Chávez, A., and Pelto, G. H. (1987). "Prevalence and age at development of enamel hypoplasias in Mexican children". *American Journal of Physical Anthropology*, 72(1), 7-19.
38. Goodman, A. H., and Rose, J. C. (1990). "Assessment of systemic physiological perturbations from dental enamel hypoplasias and associated histological structures". *American Journal of Physical Anthropology*, 33(S11), 59-110.
39. Goodman, A. H., Martinez, C., and Chavez, A. (1991). "Nutritional supplementation and the development of linear enamel hypoplasias in children from Tezonteopan, Mexico". *The American Journal of Clinical Nutrition*, 53(3), 773-781.
40. Guatelli-Steinberg, D., and Lukacs, J. R. (1999). "Interpreting sex differences in enamel hypoplasia in human and non-human primates: Developmental, environmental, and cultural considerations". *American Journal of Physical anthropology*, 110 (S29), 73-126.
41. Guntupalli, A. and Baten, J. (2009). "Measuring Gender Well-Being with Biological Welfare Indicators", in Bernard Harris, Lina Galvéz and Helena Machado (eds.), *Gender and Well-Being in Europe. Historical and Contemporary Perspectives*". Ashgate: Farnham, pp. 59-84.
42. Hansen, C. W., Jensen, P. S., and Skovsgaard, C. V. (2015). Modern gender roles and agricultural history: the Neolithic inheritance. *Journal of Economic Growth*, 20(4), 365-404.na

43. Guatelli Steinberg, D., & Lukacs, J. R. (1999). Interpreting sex differences in enamel hypoplasia in human and non-human primates: Developmental, environmental, and cultural considerations. *American Journal of Physical Anthropology*, 110(S29), 73-126.
44. Hanson, C., & Miller, H. (1997). "LEHs in medieval Scandinavia: preliminary analysis". *Dent. Anthropol*, 11(3), 9-12.
45. Hanson, C. L. (1992). "Population-specific stature reconstruction for medieval Trondheim, Norway". *International Journal of Osteoarchaeology*, 2(4), 289-295.
46. Hansen, C. W., Jensen, P. S., & Skovsgaard, C. V. (2015). Modern gender roles and agricultural history: the Neolithic inheritance. *Journal of Economic Growth*, 20(4), 365-404.
47. Hrdy, S. B. (1990). "Sex bias in nature and in history: A late 1980s reexamination of the "biological origins" argument". *American Journal of Physical Anthropology*, 33(S11), 25-37.
48. Irei, K., Doi, N., Fukumine, T., Nishime, A., Hanihara, T., Yoneda, M., and Ishida, H. (2008). "Dental diseases of human skeletal remains from the early-modern period of Kumejima Island, Okinawa, Japan". *Anthropological Science*, 116(2), 149-159.
49. Iversen, T., and Rosenbluth, F. M. (2010). *Women, work, and politics: The political economy of gender inequality*. Yale University Press.
50. Jewell, H. M. (1996). *Women in medieval England*. Manchester University Press.
51. King, A. (1978). "A comparative survey of bone assemblages from Roman sites in Britain". *Bulletin of the Institute of Archaeology*, 15, 207-32.
52. King, A. C. (1984). "Animal bones and the dietary identity of military and civilian groups in Roman Britain, Germany and Gaul. Military and civilian in Roman Britain", 187-217.
53. King, A. (1999). "Animals and the Roman army: the evidence of animal bones". na.
54. Kjellström, A., Tesch, S., and Wikström, A. (2005). "Inhabitants of a sacred townscape: an archaeological and osteological analysis of skeletal remains from late Viking age and Medieval Sigtuna, Sweden". *Acta archaeologica*, 76(2), 87-110.
55. Klasen, S. (1999). "Does Gender Inequality Reduce Growth and Development? Evidence from Cross-Country Regressions". 20779. The World Bank.

(<http://documents.worldbank.org/curated/en/612001468741378860/pdf/multi-page.pdf>)

56. Klasen, S. and Lamanna, F., 2009. The Impact of Gender Inequality in education and employment on economic growth: new evidence for a panel of countries. *Feminist Economics* 15(3) ,91–132.
57. Klasen, S., and Wink, C. (2004). “A turning point in gender bias in mortality? An update on the number of missing women”. *Population and Development Review*, 28(2), 285-312.
58. Koepke N. and Baten, J. (2005). “The biological standard of living in Europe during the last two millennia”. *European Review of Economic History*, 9-1, 61-95.
59. Komlos, J. (1998) “Shrinking in a Growing Economy? The Mystery of Physical Stature during the Industrial Revolution”, *The Journal of Economic History*. Vol. 58, No. 3.
60. Låås, J. and Kjellström, A. forthcoming. The Health of Children in Viking Age- Early Medieval Settlements
61. Lanphear, K. M. (1990). “Frequency and distribution of enamel hypoplasias in a historic skeletal sample”. *American Journal of Physical Anthropology*, 81(1), 35-43.
62. Larsen, C. S. (1995). Biological changes in human populations with agriculture. *Annual Review of Anthropology*, 24(1), 185-213.
63. Lewis, M. (2018). *Paleopathology of Children: Identification of Pathological Conditions in the Human Skeletal Remains of Non-Adults*. Academic Press.
64. Liebe-Harkort, C. (2012). “Cribra orbitalia, sinusitis and linear enamel hypoplasia in Swedish Roman Iron Age adults and subadults”. *International journal of osteoarchaeology*, 22(4), 387-397.
65. Lynnerup, N. (1998). *The Greenland Norse*. Museum Tusulanum Press.
66. Malville, N. J. (1997). Enamel hypoplasia in ancestral Puebloan populations from southwestern Colorado: I. Permanent dentition. *American Journal of Physical Anthropology: The Official Publication of the American Association of Physical Anthropologists*, 102(3), 351-367.
67. Mammen, K., and Paxson, C. (2000). Women’s work and economic development. *Journal of Economic Perspectives*, 14(4), 141-164.
68. Meinzer, N., Steckel, R. and Baten, J. (2018). “Agricultural Specialization, Urbanization, Workload and Stature” in Richard Steckel et al., *The Backbone of*

- Europe: Health, Diet, Work and Violence over Two Millennia*. Cambridge et al.: Cambridge University Press, pp. 231-252.
69. Milazzo, A. and Goldstein, M., 2017. *World development report 2017: governance and women's economic and political participation - power inequalities, formal constraints, and norms (English)*. World development report. Washington, D.C.: World Bank Group.
<http://documents.worldbank.org/curated/en/506661497953688370/World-development-report-2017-governance-and-womens-economic-and-political-participation-power-inequalities-formal-constraints-and-norms>
 70. Najjar, M. Y., DeSanti, M. V., and Ozebek, L. (1978). "Prevalence and possible etiology of dental enamel hypoplasia". *American Journal of Physical Anthropology*, 48(2), 185-192.
 71. Nake. M. Kamrany and C. Robinson (undated), "The Global Problem of Gender Inequality", Huffpost, online : https://www.huffingtonpost.com/nake-m-kamrany/gender-inequality_b_1417535.html
 72. Norling, J. (2016). *Essays on the Economics of Fertility*. Ph.D. thesis: University of Michigan.
 73. Orrman E. (2003). "The condition of the rural population". In: Helle K, editor. *The Cambridge history of Scandinavia*. Cambridge: Cambridge University Press, pp. 581-610
 74. Ortner, D. J. (2003). *Identification of pathological conditions in human skeletal remains*. Academic Press.
 75. Oyamada, J., Kitagawa, Y., Kato, K., Matsushita, T., Tsurumoto, T. and Manabe, Y. (2012). "Sex differences in linear enamel hypoplasia (LEH) in early modern Japan". *Anthropological Science*, 120–2: 97– 101.
 76. Palubeckaitė, Ž., Jankauskas, R., and Boldsen, J. (2002). Enamel hypoplasia in Danish and Lithuanian late medieval/early modern samples: a possible reflection of child morbidity and mortality patterns. *International Journal of Osteoarchaeology*, 12(3), 189-201.
 77. Roesdahl, E. (1998). *The Vikings*. Penguin UK.
 78. Salo, K. (2005). *What Ancient Human Teeth Can Reveal?: Demography, Health, Nutrition and Biological Relations in Luistari*.
 79. Sawyer and Sawyer (1993) *Medieval Scandinavia: From conversion to reformation, circa 800-1500*. Minneapolis: University of Minnesota Press.

80. Schlegel, A., and Barry III, H. (1986). "The cultural consequences of female contribution to subsistence". *American Anthropologist*, 88(1), 142-150.
81. Schultz, M. (2001). Paleohistopathology of bone: a new approach to the study of ancient diseases, *Yearbook of Physical Anthropology*, 44:106-147
82. Schultz, M., Carli-Thiele, P., Schmidt-Schultzf, T. H., Kierdorf, U., Kierdorf, H., Teegen, W. R., & Kreutz, K. (1998). Enamel hypoplasias in archaeological skeletal remains. In *Dental Anthropology* (pp. 293-311). Springer, Vienna.
83. Scott, G. R., Halffman, C. M., and Pedersen, P. O. (1991). "Dental conditions of medieval Norsemen in the North Atlantic". *Acta Archaeologica*, 62, 183-207.
84. Sellevold, B. (1989a). Fødsel og død. Kvinnors rosengård. Medeltidskvinnors liv och hälsa, lust och barnafödande, 79-96.
85. Sellevold, B. (1989b). Fokus på kvinnor. Kvinnors helse i middelalderen, belyst gjennom skjelettstudier. Kvinnors Rosengård. Stockholm: Centrum, 59-78.
86. Sen, A. (1992). Missing women. *British Medical Journal*, 304(6827), 587.
87. Siek, T. (2013). "The osteological paradox and issues of interpretation in paleopathology", *Vis à-vis: Explorations in Anthropology*, 12(1)
88. Sjöholm, E. (1978). "Rättshistorisk metod och teoribildning". *Scandia: Tidskrift för historisk forskning*, 44(2)
89. Steckel, R. H., and Rose, J. C. (Eds.). (2002). *The backbone of history: health and nutrition in the Western Hemisphere* (Vol. 2). Cambridge University Press.
90. Steckel, R. and Prince, J.M. (2001). "Tallest in the World: Plains Indian in the Nineteenth Century". *American Economic Review*, 91 (March): 287-294.
91. Steckel, R. H. (2009). "Heights and human welfare: recent developments and new directions", *Explorations in Economic History*, 46, 1-23.
92. Steckel, R. H., and Kjellström, A. (2018). "Measuring Community Health Using Skeletal Remains". In *The Backbone of Europe: Health, Diet, Work and Violence over Two Millennia*, 80, 52. Cambridge University Press.
93. Steckel, R.H., Roberts, C. Larsen, C.S. and Baten, J. (2018). *The backbone of Europe: health, diet, work and violence over two millenia*, Cambridge University Press.
94. Stini, W. A. (1985). Growth rates and sexual dimorphism in evolutionary perspective. In: R. Gilbert, J. Mielke (Eds.): *The analysis of prehistoric diets*, 191-226.

95. Storey, R. (1998). "The mothers and daughters of a patrilineal civilization: the health of females among the Late Classic Maya of Copan, Honduras". *Sex and Gender in Paleopathological Perspective*, 133.
96. Suckling, G. W., Herbison, G. P., and Brown, R. H. (1987). "Etiological factors influencing the prevalence of developmental defects of dental enamel in nine-year-old New Zealand children participating in a health and development study". *Journal of dental research*, 66(9), 1466-1469.
97. Svaleryd, H. (2009). Women's representation and public spending, *European Journal of Political Economy*, 25, (2), 186-198.
98. Swärdstedt, T. (1966). Odontological aspects of a medieval population in the province of Jämtland, mid-Sweden. Diss. University of Stockholm
99. Ward, J., B. Lee, S. Baptist, and H. Jackson (2010), "Evidence for Action: Gender Equality and Economic Growth." The Royal Institute of International Affairs. Retrieved from Chatham House website <http://www.chathamhouse.org/node/6023>.
100. Whyte, M. K. (1978). "Cross-cultural codes dealing with the relative status of women". *Ethnology*, 17(2), 211-237.
101. Williamson, N. E. (1976). Sons or daughters: a cross-cultural survey of parental preferences.
102. Winberg, C. (1985). *Grenverket: studier rörande jord, släktskapssystem och ståndsprivilegier* (Vol. 38). Nordiska bokhandeln i distribution.
103. Wittwer-Backofen, U. and Engel F. (2018). The history of European oral health: Evidence from dental caries and antemortem tooth loss. In: *Steckel et al, The backbone of Europe: Health, diet, work and violence over two millennia*. Cambridge: Cambridge University Press, 2018; 84-136.
104. Wood, J. W., Holman, D. J., O Connor, K. A., and Ferrell, R. J. (2002). Mortality models for paleodemography. *Cambridge Studies in Biological and Evolutionary Anthropology*, 129-168.
105. World Bank. (2011). *World Development Report 2012: Gender Equality and Development*. Washington, DC: World Bank.
106. World Economic Forum. (2017). The Global Gender Gap Report 2017. Retrieved from World Economic Forum website: <https://www.weforum.org/reports/the-global-gender-gap-report-2017>.
107. United Nations Developing Program (2004)#

108. Van Zanden, J. L., Baten, J., Mira d'Ercole, M., Rijpma, A., Smith, C., & Timmer, M. (2014a). *How was life?: Global well-being since 1820*. OECD publishing.
109. Yoder, C. J. (2006). *The late medieval agrarian crisis and Black Death plague epidemic in medieval Denmark: A paleopathological and paleodietary perspective* (Doctoral dissertation, University of New Mexico).
110. Zhou, L., and Corruccini, R. S. (1998). "Enamel hypoplasias related to famine stress in living Chinese". *American Journal of Human Biology: The Official Journal of the Human Biology Association*, 10(6), 723-733.
111. Zoëga, G., and Murphy, K. A. (2016). "Life on the edge of the arctic: The bioarchaeology of the Keldudalur cemetery in Skagafjörður, Iceland". *International Journal of Osteoarchaeology*, 26(4), 574-584.

Appendix

Table A1: Observations for Norse countries on relative LEH values

Country	Region	Years	Lat.	Long.	Source	Detail
Finland	Eura (Luistari cemetery)	400-500	61.1	22.1	Salo (2005)	rural
Denmark	Tirup (rural parish cemetery)	1100-1300	55.6	9.2	Palubeckaité et al. (2002)	rural
Denmark	Danish Vikings (various sites)	800-1100	55.4	13.2	Facilitated by Richard Scott	n.a.
Greenland	Early Eastern Settlement . The earliest the Þjóðhildarkirkja (Thjodhild's Church), located at the Viking Eastern Settlement. Other sites are included and are dated in different periods.	1000-1100	61.1	-45.5	Facilitated by Richard Scott	rural
Greenland	Medieval Greenland. Middle to East Eastern settlement. There are three samples: Gardar, Benedictine convent near Nassarsuaq (on Unartaq fjord), Herjolfnes (present day Ikigait)	1156-1400	60.8	-45.6	Facilitated by Richard Scott	rural
Norway	Library site in Trondheim	1100-1601	63.4	10.4	Cairns (2015)	urban
Norway	Trondheim, St. Gregory Medieval church	1100-1500	63.4	10.4	Facilitated by Richard Scott	urban
Iceland	Haffjarðarey (cemetery in a small village off the coast)	1200-1500	64.8	-22.4	Gestdóttir (2004)	rural
Iceland	Videy, Kollafirði (church cemetery)	1200-1774	64.2	-21.9	Gestdóttir (2004)	urban
Sweden	Medieval Lund, old Denmark (three adjacent cemeteries)	900-1100	55.7	13.2	Arcini (1999)	urban
Sweden	Medieval Lund, old Denmark (three adjacent cemeteries)	1100-1300	55.7	13.2	Arcini (1999)	urban
Sweden	Medieval Lund, old Denmark (three adjacent cemeteries)	1300-1536	55.7	13.2	Arcini (1999)	urban
Sweden	Sigtuna (urban, graves from churchyards and burials)	980-1100	59.6	17.7	Kjellström et al. (2005)	urban
Sweden	Sigtuna (urban, graves from churchyards and burials)	1100-1300	59.6	17.7	Kjellström et al. (2005)	urban
Sweden	Sigtuna (urban, graves from churchyards and burials)	1300-1527	59.6	17.7	Kjellström et al. (2005)	urban
Sweden	Jämtland (located in Frösön in lake Storsjön)	1000-1300	63.1	14.2	Swärdstedt (1966)	rural

Note: This table includes the observations collected in addition to those available in the EHHP (Steckel et al. 2018). Richard Scott provided the data on LEH for Danish Vikings, Greenland, and the Saint Gregory Medieval church in Trondheim. With regard to the Danish Vikings, we only know that most observation are from Trelleborg (Sweden) and comprehends a mix of Danish and Swedish Vikings (dating between A.D. 800 and 1000).

Table A2: Descriptives: composition by region and urban/rural (both genders)

	Sites	% of all sites	Individuals
<i>Regions</i>			
Central and South-Eastern Europe (cseeuropean)	19	20	2211
Mediterranean (mediterranean)	15	15.79	192
North-Eastern Europe (neeurope)	30	31.58	2212
Northern Europe (neurope)	10	10.53	745
North-Western Europe (nweurope)	21	22.11	1654
<i>Urban/Rural</i>			
Rural	62	65.26	4622
Urban	33	34.74	2392
Total	95	100	7014

Note: the same cases are included as in Table 2, columns (3) and (5).

Table A3: LEH values of males and females

	Variable	Obs	Mean	Std. Dev.	Min	Max
Europe (all)	LEH Females	95	0.476	0.270	0.029	1.000
	LEH Males	95	0.489	0.251	0.033	1.000
Rural Scand.	LEH Females	10	0.345	0.249	0.077	0.827
	LEH Males	10	0.500	0.238	0.175	0.883
Other Europe	LEH Females	85	0.491	0.269	0.029	1.000
	LEH Males	85	0.487	0.254	0.033	1.000

Note: the same cases are included as in Table 2, columns (3) and (5).