

Multidimensional Patterns of European Health, Work, and Violence over the Past Two Millennia

Joerg Baten, Richard H. Steckel, Clark Spencer Larsen and Charlotte A. Roberts

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Using human skeletal remains, a joint large-scale project of economic historians, physical anthropologists and bioarchaeologists traces health, workload and violence in the European population over the past two millennia. This study summarizes the main findings: Health was surprisingly good for people who lived during the early medieval period. The Justinian plague of the sixth century was ultimately beneficial for health because the smaller population had relatively more resources that contributed to better living conditions. Increasing population density and inequality in the following centuries imposed an unhealthy diet – poor in protein – on the European population. With the onset of the Little Ice Age in the late middle ages, a further health decline ensued, which was not reversed until the nineteenth century. While some aspects of health declined, other attributes improved. During the early modern period, interpersonal violence (outside of warfare) declined possibly because stronger states and institutions were able to enforce compromise and cooperation. European health over the past two millennia was hence multifaceted in nature.

The aims of the project

In this study, we discuss the underlying methods of the “Backbone of Europe” project and synthesize its main results. This project is the result of the efforts of a large team of bioarchaeologists, economists, demographers, and historians to measure and analyze health from the skeletal remains of 15 119 individuals who lived in Europe over the past two millennia. This unprecedented collaborative effort brought together 17 principal investigators and more than 75 bioarchaeologists from Europe and the United States who coordinated data collection and contributed data. The data were compiled using the same recording protocol to document data from the skeletal remains of the whole sample, buried at 103 localities across Europe (representing 16 modern European countries) and dating from the third to the end of the nineteenth century CE.¹ In the process, we initially created a codebook that outlined the variables to be recorded for each skeleton and the methods to be used, and developed software to code the skeletal data online in a standard and consistent manner. We also created a series of tests to measure inter- and intra-observer error. These data were then systematically analysed to provide customized results to individual researcher teams for interpretation. The key context variables are socioeconomic status (farming community, craft or artisan workers, religious order, hospital population, other); settlement size (rural, village, and town, and small, large and mega cities); topography (coastal, major river flood plain, valley of a major river, plains, and rolling (low) hills); elevation (sea level-100m, 100-300m, and 300-1000m), and time period (pre-medieval, early medieval, high medieval, late medieval, early modern, and industrial).

¹ The effort extends an earlier but smaller project for the Western Hemisphere (Steckel and Rose, *The Backbone of History*, Cambridge University Press, 2002) by collecting data in a standardized way on more skeletal measures of health, and by adding a substantial number of contextual variables to aid interpretation.

This is the first such work to compile a bioarchaeological data set of this size and scope that addresses methodological consistency but also long-standing issues relating to health and disease on a Europe (see Steckel and Rose, 2002, on the Americas).

Hence, the project constructed the largest consistently recorded dataset based on human skeletal remains from archaeological sites to date, and is the first to explore health, nutrition, physical activity, and violence over almost two millennia of European history from such a dataset. Because it combines both anthropology (in particular biological anthropology, bioarchaeology, and archaeology) and economics (economic history, health economics, demography, and development economics), it makes a significant contribution to the published literature on the history of human health, being a unique contribution to understanding past health based on human remains from archaeological contexts. This book has brought together a wide range of different skeletal indicators that inform us about the development of health and well-being in past populations of Europe. Other indicators give clues about the development of violence and of workload intensity of Europeans who lived during this long time frame.

In this study, we first summarize the methods and challenges of our data collection (Section 2). Next, we compare the cross-sectional results relating to the effects of urbanization (reflected in settlement size), topography, and socioeconomic status on health that have been identified in Steckel et al. (2018) (3). In section 4, we compare the trends of our indicators of health, workload, and violence. We find that the trend for some skeletal indicators was the same, as expected, as they reflect similar aspects of health. We assess, for example, whether the indicators femur length, hypoplasia and dental health – which normally reflect the quality and quantity of

nutrition and disease situation during childhood – moved into a similar temporal direction. We present the results of the study in the context of recent research on long-term trends in European incomes and inequalities from historical records. Other indicators (of workload, violence, and anemia) clearly show a fundamentally different trend, indicating the multidimensional nature of health and well-being.

2 Methods and challenges of our data collection and analysis

2.1 Skeletal measures of health

Because invasive analyses, such as biomolecular analysis, would have required special permissions and would not have been practical for a sample of this size, we designed an illustrated codebook that included descriptions of the variables that were possible to record visually without access to more complex methodology (see chapter 14 in Steckel *et al*, 2018).

The following variables were recorded: estimates of sex and age at death, maximum femur length (as a proxy for attained adult stature), and various health indicators. These indicators included periosteal reactions, a pathological condition that can be caused by a number of factors, including injuries to the periosteum that could have been followed by *staphylococcal* or *streptococcal* infections, and a potentially-weakened immune system; oral health (abscesses, caries and tooth loss); linear enamel hypoplasias (enamel defects on permanent teeth formed in early childhood, which signify bouts of serious illness or dietary deficiency); cribra orbitalia and porotic hyperostosis (pitting on the skull and eye orbits that can develop in early childhood, which can indicate iron and/or vitamin deficiencies, amongst other causes); trauma prior to death (identified by healed weapon wounds and healed or partially healed bone injuries); and degenerative joint disease. The health measures

were graded by severity. The skeletal remains studied ranged in date from a single year to hundreds of years at any one location. Hence, it was impossible to identify birth cohorts, which complicated linkage of health to external events such as climate.

2.2 The database

We adopted a stratified procedure, seeking representation by geographic location, socioeconomic status, settlement size, topography, elevation, and time period. The sample size is 15 119 individuals, and every century from the third to the nineteenth centuries is represented by several hundred individuals, with the largest coming from the seventh, sixteenth, seventeenth, and nineteenth centuries. Northeast and southeast and central Europe provide the largest share of the sample (about 40% each) and the Mediterranean contributed 4.5 %. The numbers vary by settlement size, ranging from 40% rural to 24% town or villages, and the remainder lived in cities of various sizes (see Chapter 2 by Jankauskas and Grupe in Steckel *et al.*, 2018).

2.3 Measuring community health.

A person's health history has two important components, namely, length of life and morbidity. The former is difficult to measure in archaeological settings because the number of individuals at risk is typically unknown. The skeletal measures at hand, however, represent important aspects of health while living. Under defensible assumptions, a procedure called the health index (discussed in Chapter 2 of Steckel and Rose, 2002) converts the skeletal measures into age-specific rates, which are then imposed on a model west level 4 life table, which arguably represents (approximate) longevity conditions in pre-industrial Europe (see the Chapter 3 by Steckel and Kjellström in Steckel *et al.*, 2018, on details). The result is a measure of quality-

adjusted life years. The procedure removes any genuine differences in life expectancy across sites from the measure of health. However, if morbidity is inversely correlated with longevity, the measure is a useful surrogate for health.

3 Effect of ecological variables: settlement size, topography, and socioeconomic status

In this volume, we assessed health, the impact of workload, and the experience of violence in Europeans in different environments, including urban and rural settings. Today, in the twenty-first century, health standards in Europe and North America are usually higher in large urban environments, even if there are still major challenges such as air pollution, poverty, variability in access to resource, and other factors. For example, the longevity gap between rural and urban dwellers in the U.S. widened from 0.4 years in the period 1969-1971 to 2.0 years in 2005-2009 (Singh and Siahpush, 2014). Although there is more variability of urban-rural differences in other countries and world regions, Dye (2008) concludes that typically urban health is better than rural health. The urban density of hospitals per capita is higher, and favorable urban incomes provide access to better health care. However, the human species originally lived as hunters and gatherers for millennia in the natural environment, and even after the introduction of agriculture less densely populated settlements were usually healthier than the urban locations later in time (e.g., see Cohen and Armelagos, 1984; Cohen and Crane-Kramer 2007). It remained challenging to maintain health in urban environments, and a substantial literature has addressed the “urban penalty” phenomenon (Szreter and Hardy, 2001; Dye 2008). This literature has characterized metropolises such as London and Paris in the nineteenth

century as “urban graveyards,” in which life expectancies were remarkably low. In this volume, we add a longer time perspective to the following question: Was there an urban health penalty during the Middle Ages, and did urban dwellers live shorter lives than rural populations in the Roman Empire?

Studying the evidence of the urban penalty in pre-modern Europe, we observed that some of the indicators seem to display a substantial penalty. For example, femur length values for the industrial and for pre-modern Roman Antiquity, show a very substantial urban penalty (Chapter 8 by Meinzer, Steckel, and Baten in Steckel *et al.*, 2018). The dental health patterns confirm this. In particular, in terms of dental health, females were more exposed to urban disadvantages (Chapter 4 by Witwer-Backofen and Engel in Steckel *et al.*, 2018). Surprisingly, the urban penalty in femur length was mostly absent during the medieval period. However, compared to Roman Antiquity and the Industrial Period, urban centers of the Middle Ages were much smaller. Hence, the effects of infectious disease and pollution might have had more modest effects during the Middle Ages than in these other periods.

In terms of linear enamel hypoplasia, we conclude that urban dwellers with higher incomes sometimes attained a better nutritional status because they had the possibility of buying pork, grain, salted fish, and salted meat (Chapter 6 by Bereczki, Teschler-Nicola, Marcsik, Meinzer, and Baten in Steckel *et al.*, 2018). This partly outweighed the more adverse disease environment of urban locations, at least for the wealthy. In a similar vein, topography mattered. That is, people living in the coastal regions benefitted from the trade of food, gaining a relatively greater access to nutrition, which may explain their relatively lower prevalence of hypoplasia. The reason for their better health status might be that local harvest failures could be buffered and compensated using available trading possibilities.

Living in an urban location was also a substantial advantage if violence is considered, particularly in the Middle Ages. A decline in violence took place in urban areas first, whereas for the rural population this only occurred after a significant time lag.

Closely related to urban-rural health effects are inevitable occupation differences affecting health, reflecting socioeconomic status. A large share of our sites were farming communities. A smaller, but still substantial number of skeletons originated from settlements of craftsmen. Tiny shares of the sample were religious communities, military units, and other groups. Because the farming communities lived in rural environments, the urban penalty of femur length that we described above does not apply to them. However, subsistence farmers, who consumed mostly their own products, suffered to a certain extent because of their relatively isolated rural existence. That is, when harvests failed they were not buffered by market integration (see the hypoplasia results above). Food in regions producing a surplus could not easily be sold to the regions most severely hit by harvest failures, if market integration was insufficient. This hypothesis is strengthened by the fact that farmers had high cribra orbitalia values: while they often had adequate nutrition, in harvest failure situations, subsistence farmers in the affected regions suffered badly, leading to high rates of dietary deficiency, which contributed to iron deficiency anemia and the associated pathological condition of cribra orbitalia (Chapter 7 by Papathanasiou, Meinzer, Williams, and Larsen in Steckel *et al.*, 2018).

A very important finding for this “occupational” group is the extreme workload that was detected in the farmers’ skeletons. The degenerative joint disease (DJD) values were enormously high. The most extreme cases were male farmers during the early medieval period, a period which was characterized by low population

size relative to available land, making large plots of land available to farmers. However, the DJD record suggests that they were exposed to demanding work environments, leading to the highest DJD prevalence during this period (Chapter 9 by Williams, Meinzer, and Larsen in Steckel *et al.*, 2018). Early medieval farmers also took care of large numbers of cattle. While this was beneficial for maintaining nutritional quality with respect to access to animal sources of protein, they experienced injuries to their lower limbs which may have been related to interactions with their animals. Cattle herding certainly expose individuals to injury. In this regard, injuries may explain some of the osteoperiostitis documented in this study (see chapter 5 by Marques, Matos, and Meinzer in Steckel *et al.*, 2018). We observed that periostitis values were quite elevated in this early medieval period. Finally, farming communities were much more often victims of violence during the medieval period. Within the city walls, violence began to decline during the high and late medieval periods, whereas farmers were still experiencing high levels of cranial trauma resulting from interpersonal violence (Chapter 10 by Baten and Steckel in Steckel *et al.*, 2018).

In summary, the occupational-related differences between farming communities and craftsmen (the comparison group here) showed some advantages for the farmers (less urban penalty, but this was compensated for by injuries from a high workload and a high degree of violence encounters).

Health differences related to topography and altitude were limited in this study. For example, Europe did not have as many malaria-intensive river deltas as the other continents, reducing the role of this topographic factor (although malaria played a role in Europe, too, Majori, 2012). Two opposing economic forces influenced the health characteristics of coastal and large river locations (often combined with low

altitude). On the one hand, population contact was much higher in the coastal and river locations (compared to hilly areas at higher altitude), which created living conditions conducive to infection and infectious disease. On the other hand, these very same regions benefitted from trade and sometimes higher incomes. Dental health problems, for example, were clearly lower at low altitudes and river/sea locations. Similarly, we observed more cribra orbitalia in coastal, low altitude environments (Ch. 7). In contrast, DJD did not vary as much by topography and altitude. These findings suggest that the kind of intensive work associated with DJD may have been accomplished everywhere, especially by farmers. Similarities by topography and altitude also apply to many other indicators studied in this volume.

Finally, regional differences within Europe are remarkable in some of the indicators. The femur length analysis indicates that Northern Europe already had the highest values during medieval and pre-medieval times, whereas the Mediterranean had the lowest values. These regional differences are actually quite similar to today's differences in height. Koepke and Baten (2005, 2008) argued that these differences were caused by agricultural specialization, and milk production and consumption in particular. That is, before the twentieth century, milk could not be transported and stored for long periods, and cheese production did not play a quantitatively large role in diets of communities in most regions and periods. The particularly high calcium and vitamin content of milk as well as its high-quality proteins led to taller heights (and longer femurs) across the whole period (for a more differentiated view, see Chapter 2 by Jankauskas and Grupe in Steckel *et al.*, 2018).

A gradient from the Northwest to the South and East was visible in violence levels. In this regard, northwestern Europe had achieved an earlier decline in violence, as became visible in our analysis of cranial trauma and weapon wounds. The lowest

medieval values were obtained in the trading centers of what are today the Netherlands and northwestern Germany. Trade required investments in security and policing. Moreover, this region became a focal point of elite education during the Middle Ages, as is visible in the high number of medieval monastery manuscripts (Bosker, 2013).

A separate chapter of the volume studies the impact of early life conditions on age-at-death (Chapter 11 by Roberts and Steckel in Steckel *et al.*, 2018). Nutritional deficiency and childhood diseases had a strong impact on the age at which the individuals of our sample died. If malnutrition was so extreme that cribra orbitalia, porotic hyperostosis, or enamel hypoplasia formation occurred, this affected survival, as the chapter demonstrated. The severity of malnutrition resulting in earlier death gives a terrifying record of the effects of living conditions in medieval and early modern Europe.

4 Long-term trends of health, workload, and violence

The traditional view about the history of health over the last two millennia suggests that the Renaissance period rediscovered the medical insights of Roman and Greek antiquity, and after modest progress in the early modern period, the twentieth century saw a rapid development of modern medicine. The “Dark Ages” between Roman Antiquity and the Renaissance of the fourteenth and fifteenth centuries are an important element of this story, during which medical knowledge declined to very low levels and certainly did not experience progress according to written records. Monastic hospitals provided a limited amount of medical aid, but the quality of care was modest and mainly palliative (Porter, 1997). Some of the medical knowledge might have been retained by oral traditions and used particularly by women in local

communities, but given our lack of written sources on this period, there is little known. However, does this description of the history of medical knowledge also imply a corresponding improvement in health of the population?

This is not what was found in our project. We observed quite the opposite: During the early Middle Ages, precisely after the decline of the Roman Empire in the West, health and nutritional quality was the highest. We observed this using a set of three different indicators, which all point in a similar direction (Figure 1). The health index values for femur lengths and dental health suggest an increase from pre-medieval to early medieval times, and an almost constant value in the case of hypoplasias. Following the early medieval period, all three indicators follow a long-term decline up to the industrial period. These three indicators have been transformed as described in the health index chapter in a way that higher values indicate better health (Chapter 3 in Steckel *et al.*, 2018).

The parallel movement of femur length and hypoplasia trend is not especially surprising, because both indicators represent health and nutritional quality during childhood. However, this finding also suggests that measurement error and potential selectivity bias are probably not confounding issues. Per our analysis of dentition, oral health has also a very similar development, except that there is no difference between the early and the high medieval values. Oral health as represented by dental caries and antemortem tooth loss is sensitive to carbohydrate consumption generally, including sugar, but the quantities of sugar were small prior to its industrial production beginning in the nineteenth century (Ch. 4; see also Müller and Hussein, 2017). The downward trend of oral health before the sugar era is best explained by an increasingly starchy diet, as the authors explain (Ch. 4). During the industrial period, dental caries was so widespread that even females of young adult age suffered

heavily. We estimate that every second young adult female experienced ante-mortem tooth loss, whereas during the Middle Ages and the early medieval period, in particular, the situation likely improved, at least as can be measured by this sensitive indicator.

What might explain these trends in health? Agricultural specialization mattered strongly for quality of nutrition during the Early Middle Ages when cattle per capita values were high and the protein provision from milk and meat was easily accessible for a relatively large share of the population. In the later medieval and early modern period, cattle per capita and femur length values declined. The population was experiencing a starchier diet consisting of carbohydrates derived from grains, especially for lower-income groups. In concert with increased carbohydrate consumption, access to animal sources of protein declined. This overall nutritional deterioration interacted with infectious diseases, owing to the synergistic relationship between infection and malnutrition, a pattern now well documented in a range of contexts worldwide (Larsen, 2015).

Although these three indicators – femur length, LEH, and dental/oral health indices – showed a similar trend, cribra orbitalia and porotic hyperostosis shared this development only during the first three periods of our study (Figure 7.1 in chapter 7 in Steckel *et al.*, 2018). Cribra orbitalia and porotic hyperostosis prevalence indicates a decline in health until the High Middle Ages. However, during the Late Middle Ages, the early modern and industrial periods, these indicators showed values suggesting more positive health. If that is true, then why might this have been the case? Several possibilities come to mind. One explanation may be that cribra orbitalia and porotic hyperostosis indicate very severe malnutrition. In chapter 11 in Steckel *et al.*, 2018, Roberts and Steckel find that cribra orbitalia and porotic hyperostosis are very closely

correlated with the probability of individuals reaching age 35, rather than dying at younger ages. Hence, it might be that during and after the Late Middle Ages the osteological paradox played an important role. That is, individuals with extreme anemia died very young, and skeletons of very young infants are often underrepresented in archaeological samples. Hence, it could be that people with cribra orbitalia or porotic hyperostosis might be less represented in the last three time periods.

A second potential explanation is that food markets were extremely underdeveloped during the early and High Middle Ages, although the general food supply overall might have not been as deficient. In later periods, the prevalence of indicators representing malnutrition was slightly more distributed among a larger number of people. However, in the early and High Middle Ages, when cranial porosities were at their highest prevalence, the lack of good market integration had the implication that isolated subsistence farmers, for example, experienced in some years extreme malnutrition.

In conclusion, most of the health indicators analyzed for this ambitious study suggest declining health since at least the early medieval period. These indicators also suggest an improvement in living conditions after the fall of the Roman Empire on average. Is this plausible? After all, the predominant view of the early medieval period is one of urban decay and decline, low levels of education, and violence, and for many dimensions of human welfare, such as a personal security or education, this low level is true as we will discuss in the following. However, nutritional quality and health do not necessarily develop in the same direction as personal health and education. Cohen and Armelagos (1984) argued that the early transition to agriculture and the urban development of the eastern Mediterranean had negative health

implications, even if food production increased, and more humans could be nourished. Similarly, Steckel and Rose (2002) argued that the Western Hemisphere also experienced a decline in health over a very long period of time (for European heights see Steckel, 2004; Koepke and Baten, 2005; 2008). For most of the population, this health decline and the worsening of nutritional quality was probably the dominant effect, whereas a small part of the elite might have had better welfare during this period. This interpretation of welfare development has been supported by recent income estimates. For example, Broadberry (2016) and his project colleagues estimated that medieval incomes were higher than the earlier estimates suggested (for example, see Maddison 2001).

Taking all this evidence together, we would argue that the Justinian plague and the implosion of the West Roman Empire were among the strongest determinants of European health history over the last two millennia (before the late nineteenth century). These dramatic events reduced the population in Europe enormously, and engendered a more protein-rich diet for the following generations. The Justinian plague hit Europe probably even harder than the Black Death of the fourteenth century, although much less is known about the earlier of these two plague events. Given its prominent role for the health history of Europe, we will describe the plague in some detail in the following (whereas the equally important history of state failure of the West Roman Empire has been discussed multiple times; see Scheidel, 2017).

In the year 541 CE, the Justinian Plague was first documented in the city of Pelusium between Egypt and Palestine, and it soon began to spread to Egypt and Gaza (Scheidel, 2017; Stathakopoulos, 2004). The plague reached Constantinople in 542 CE. The contemporary descriptions of the events show a picture of one of the most terrible episodes of human history, in which “*the dead outnumbered the living.*”

Although families first tried to tend their dying, there were terrible scenes later, when everything was in complete disorder. Regarding disposal of the remains of deceased loved ones and community members, “*They piled them up just as each one happened to fall and filled practically all the towers with corpses and then covered them again with their roofs..*” (Scheidel 2017, p. 320).

The epidemic spread rapidly over the whole empire, devastating Syria, North Africa, Italy, Spain, and the Balkans in 543 CE. There were 18 separate outbreaks between the mid-sixth and the mid-eighth centuries. All provinces and areas between Yemen and Britannia experienced dramatic population decline. DNA analysis has revealed that the cause of the disease was, in fact, the Black Death bacterium (*Yersinia pestis*). In Aschheim, a late Roman cemetery, the entire DNA sequence of the bacterium could be identified (Harbeck *et al.*, 2013). The overall impact of the Justinian plague on the European urban population has been estimated to have been considerable, killing one half of the population, although estimates for such this earlier plague are necessarily vague.

Wages typically increase after a plague event (or another event that drastically reduces the population), and inequality between poorer wage earners and richer land-owners declines (Scheidel, 2017). The East-Roman Emperor Justinian tried to react to the plague by constraining the wages of workers (who demanded double and triple wages because workers were in short supply). He reminded them that they should not demand more than what ancient custom prescribed. However, this first attempt to restrict bargaining power after such an epidemic disease did not have lasting effects (Scheidel, 2017). Similar to wage-constraining measures after population declines in late-medieval England and France or in early-modern Spanish Mexico, the demand for labor was simply so large that real wages increased.

Pamuk and Shatzmiller (2014) and Scheidel (2010) provide evidence in wages for the period before, during, and after the Justinian plague, although it is unfortunately limited to Egypt (as Figure 2). However, it can be safely assumed that this change in wages also took place in many areas of Europe, where the population was similarly reduced. Pamuk and Shatzmiller (2014) suggested that after the plague, there was a strong increase in animal husbandry and the consumption of meat and derived products. The effects on income and wealth inequality can only be assumed, but it seems likely that income inequality contracted strongly after this major disease event, as it did after the Black Death of the fourteenth century, and similar plague waves. The Justinian plague is probably one of the key major “events” in inequality history before the “Great Compression” of the 1920s-70s in the United States and Western Europe. The effects of the plague were reinforced by the failure of the state in the West Roman Empire. During the fifth and sixth centuries, the enormous and unprecedented riches of the Roman elite families disappeared, first in North Africa, Gaul, and Spain, and later in Italy itself (Scheidel 2017).

Similar real wage evidence for the thirteenth to eighteenth centuries leads us to conclude that before the Black Death of the 1340s real wages were low, and inequality was high (Broadberry, 2016). However, soon after this major demographic catastrophe, wages reached a very high value, because labor had become scarce. Alfani and Ammanati (2014) estimate inequality trends for Italy between the thirteenth and the eighteenth centuries (Figure 3). Their evidence suggests that inequality was high before the Black Death, and low thereafter. From this low point after the “plague event” inequality immediately started to increase again. The similarities of the Justinian plague of the sixth century are quite apparent (and the plague wave of the 17th century had similarities, although to a slightly smaller extent).

For the period before the late 19th century, the Malthusian effect seemed to characterize the waves of population growth and real wages and health decline quite reasonably, in spite of growing skills, trade, and government abilities. Only after the 19th century did European countries escape this mechanism. However, the health trends in skeletons analyzed in this project suggest that the Justinian plague (and the failure of the state in the West Roman Empire) had the strongest impact on health history.

In a separate study, adverse climate conditions were considered, alongside health indicators. Apart from plague and state failure, these conditions clearly mattered. Steckel and Engel (Chapter 12 in Steckel *et al.*, 2018) show that colder climates reduced the probability of good harvests and had an additional direct impact on health. The Little Ice Age particularly imposed an additional burden on medieval and early modern population. Moreover, the dental health chapter In Steckel *et al.*, (2018) also discusses the effect of climatic and other variables and the composition of the diet more extensively. The effect of climate is slightly heterogeneous whereas it had an impact on various components of health.

The study of osteoperiostitis qualifies a positive view of health during the early medieval period (Ch. 5). This study finds a maximum frequency of periosteal reactions (PR) during the Early Middle Ages. This is interesting because it shows that not all health components need to move in the same direction. PR and femur length also showed a negative correlation in the Western Hemisphere project (Steckel and Rose, 2002). In particular, prairie-based nomadic tribes in North America, such as the Cheyenne and Sioux, had long femurs (and by implication tall stature) but also a high level of periosteal reactions. One factor which the prairie Indians and the European population had in common was the high number of large animals per capita, much

higher than before or after the early Middle Ages in the case of Europe. The presence of large animals could have – at least partially – contributed the opposite trend in this health indicator.

Trends in Workload

In this volume, the workload of European societies was traced for the first time using a long time perspective (Ch. 9). Available technology, population density, inequality, and other factors mattered in relation to the impact of work on people's bones. For example, evidence of the impact of work on the upper arm bones was particularly high in the pre-medieval and early medieval period whereas the situation improved in the high medieval period. The technological breakthrough of the heavy plough might have partially caused this (Figure 4). The record for degenerative joint disease (DJD) for the elbow joints and the robustness of the humeri indicated a slightly lower workload during the high Middle Ages. However, between the high medieval and the early modern period the trend reversed. The growing social inequality during the early modern period and declining wages required a higher workload per worker in order to make a living, especially so for agricultural day-laborers. The economic history literature has focused on this phenomenon as the "Industrious Revolution" which preceded the Industrial Revolution (de Vries, 2008). As documented in the skeletal record in this study, we observed that workload increased during the early modern period. Only during the nineteenth century did technological progress reach the stage where the most physically-demanding work could be carried out by machinery. As new tools and technology replaced human effort in its most extreme form, DJD rates and the robusticity of bones subsequently declined.

Trends in Violence

European violence history took a very different path compared to the history of health, nutritional quality, and workload (Figure 5). We find that there was no substantial decline in violence until the late medieval period. In fact, violence according to cranial trauma and weapon wound evidence was even higher in the late medieval period. Only thereafter did a rapid decline begin, with the decline being earliest and fastest in the urban centers, whereas farmers were more often victims of violence even in later periods. Comparing different European regions, we found that the lowest levels of violence were visible in the North Sea region and within this region close to the trading centers of what became later the Netherlands and northwestern Germany.

In summary, the histories of health, nutrition, workload, and violence show a multifaceted picture of European development over the last two millennia, with more positive aspects represented by the movement from violence to personal security, and a dramatic decline in health and nutritional quality (negative). The latter trend was remarkably reversed during the late nineteenth century.

5 Comparisons with the Western Hemisphere

How did Europe develop in comparison with the Western Hemisphere, a vast region of the globe dominated by the continents of North America and South America (Steckel and Rose, 2002)? In line with the long-term downward trend in health in the Western Hemisphere over most of the past five millennia, European populations also experienced declining health and nutritional quality. In our European femur length,

hypoplasia, and dental data, a similar long-term declining trend can be observed. However, the early European development was also characterized by temporary upward deviations in health, most notably between the pre-medieval and early medieval period.

Similar are also the violence patterns between the continents. In the Western Hemisphere, highly organized societies such as the Maya or other Central American groups had relatively low levels of interpersonal violence in their cities. Human sacrifices for which they were famous involved just a small portion of the population. In contrast, nomadic tribes, which had a reputation for military activities like the Cheyenne, displayed very high values for violent trauma. This pattern can also be observed for Europeans. That is, urbanized Northwestern Europeans show relatively low trauma values, whereas the values for sparsely populated Eastern and northern Europe were exceptionally high.

6 Executive summary: some remarkable findings

One important conclusion of this project is the unexpectedly favorable health situation for people who lived during the early medieval period. The tremendous reduction of the population during the Justinian plague and the end of the West Roman Empire had a strong impact on health, because the much smaller population was likely better nourished. This development is even more dramatic in comparison to other periods such as during Roman Antiquity or the early modern period where the population grew rapidly and important nutrients became scarce. An adverse development since the early medieval period was visible for stature (femur length), linear enamel hypoplasia prevalence, and oral health (dental caries, antemortem tooth loss). That is, for the three indicators, we observed an improvement between the pre-

medieval and the early medieval period, followed by a long-term decline until the industrial period. Only during the late nineteenth century did health and nutritional quality increase to unprecedented levels.

We find that the Justinian plague and the state failure of the Western Roman Empire played a major role for early European health history. It is in these settings that several outbreaks of the plague between the sixth and eighth centuries contributed to considerable reduction in population. Only thereafter did a recovery of the European population become possible. Even the late medieval Black Death of the fourteenth century left only a more temporary mark compared with the Justinian plague - the heavy population losses of the Black Death were relatively rapidly compensated for by a population increase in the following two centuries. Although Europe's nutritional situation at this time not bad, one disadvantage of the early medieval period was the unusually high workload experienced, especially for farmers. In this regard, their degenerative joint disease prevalences indicate that they shouldered an enormous work effort, and the high values for osteoperiostitis might suggest that farming also took its toll on the lower limb bones.

Although health and nutritional quality might have worsened over most of the period investigated in our analysis, we observe substantial improvements in social interaction during the early modern and the industrial period. The frequency rate for cranial trauma and weapon wounds indicates that conflicts declined. After the late Middle Ages, potentially violent encounters were settled more often with compromise and compliance with rules. The trends in violence hence differed from that of health and nutritional quality. If a general conclusion can be drawn from the history of European welfare over the past two millennia from this volume, it is that it was multifaceted in nature. In particular, many different components must be weighed

against each other, because some of them – such as personal security – might partially compensate the more adverse development of others.

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##The Backbone of Europe:

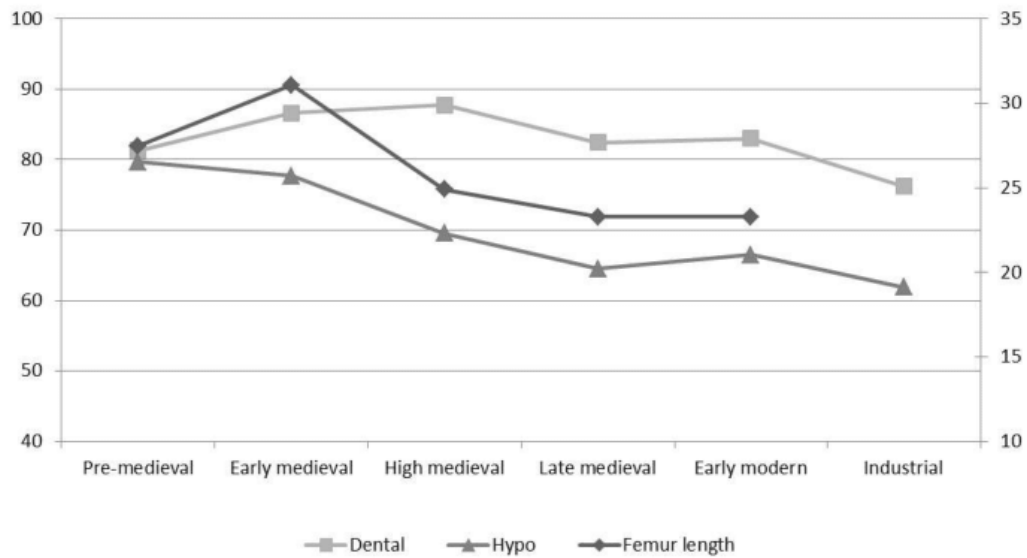
Health, Diet, Work, and Violence over Two Millennia

Edited by Richard H. Steckel, Clark S. Larsen, Charlotte Roberts and Joerg Baten

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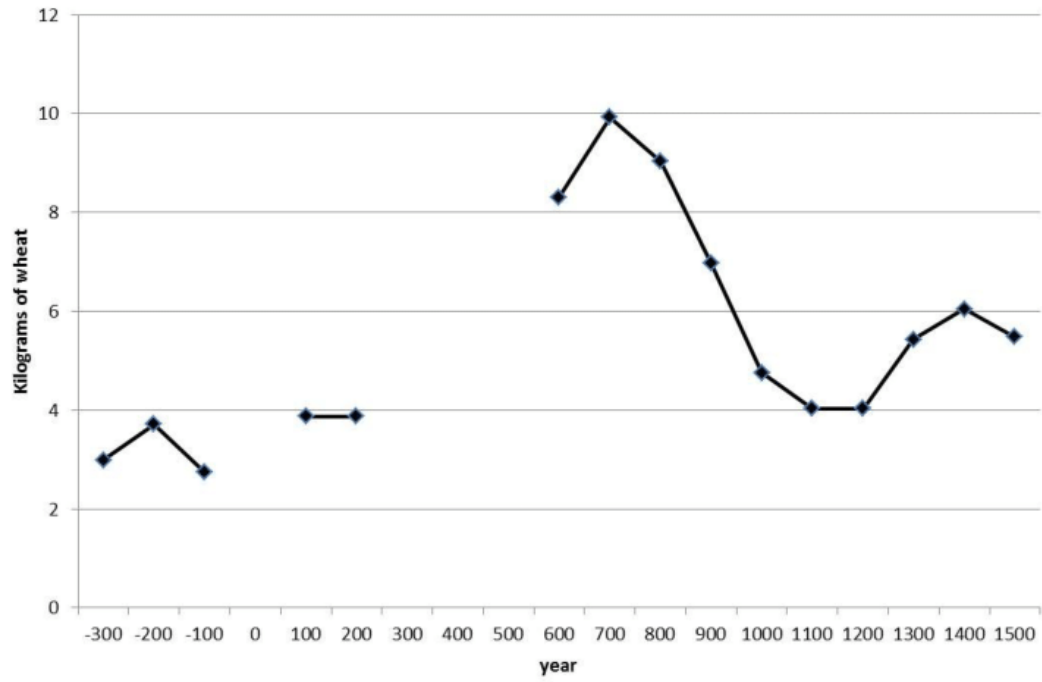
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14. Appendix 1: Data collection codebook
Richard H. Steckel, Clark Spencer Larsen, Paul W. Sciulli, and Phillip L. Walker

Figure 13.1 Trends in Health using Dental Health Index, Absence of Hypoplasia Index (both on left scale) and the Femur Length Index (right axis)



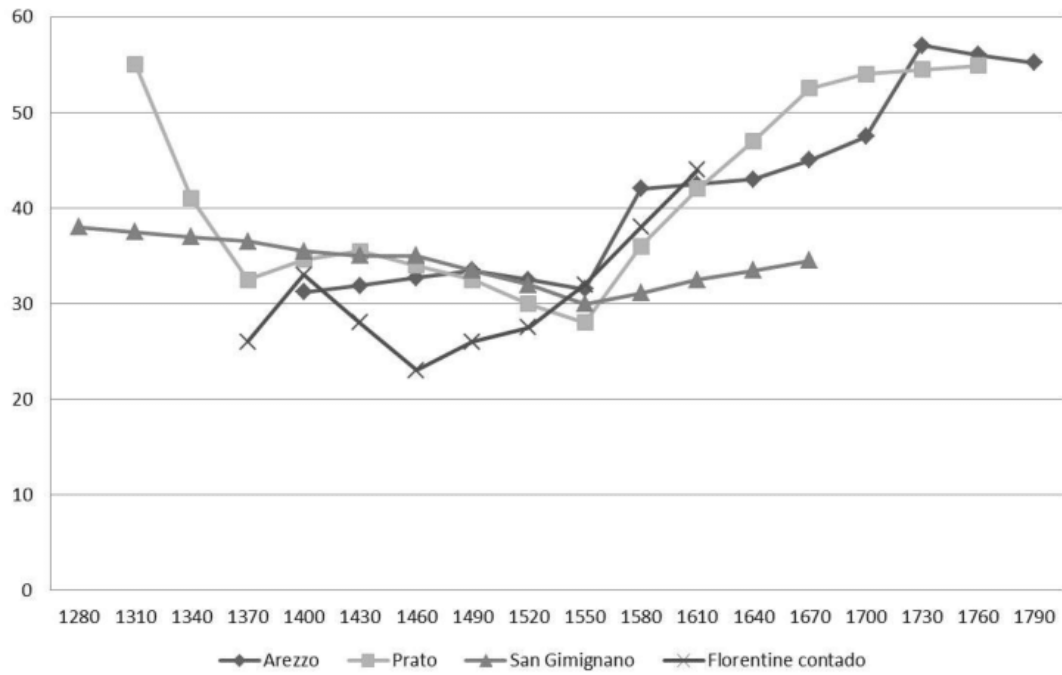
NOTE: Sources: see the Chapters on Dental Health, Hypoplasia and Femur Length in this volume. These health trends are based on health index components as defined in Steckel and Kjellström's chapter on health index values. All 103 sites are included. All the variables are scaled such that higher values 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.

Figure 13.2 Purchasing power of wages (i.e. low income groups) before and after the Justinian Plague in Egypt



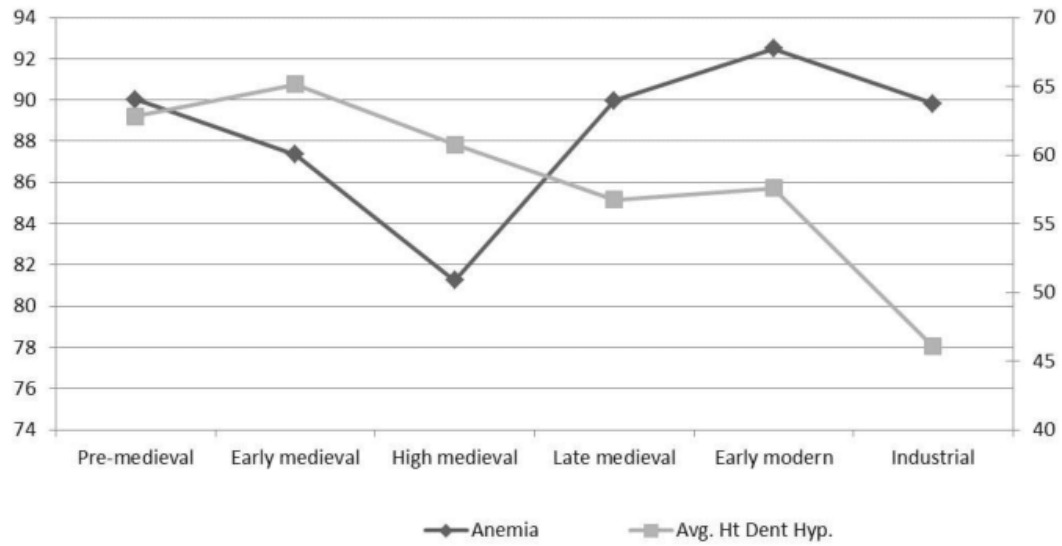
NOTE: Source: redrawn and modified from Scheidel, 2017, and Pamuk and Shatzmiller (2014)

Figure 13.3 Inequality in Italian cities before and after the Black Death (1340s and thereafter)



NOTE: Source: redrawn and modified from Alfani and Ammanati (2014)

Figure 13.4 The Absence of Excessive Workload measured by Robusticity of the Humerus (right axis) and by the Absence of Degenerative Joint Disease in the Elbow (left axis)



NOTE: Source: Chapter 8 on femur length and 9 on DJD (Degenerative Joint Disease) in this volume. The values are expressed as health index values between 0 and 100 (DJD, left axis), and the inverse of robusticity as presented in Figure 8.14.