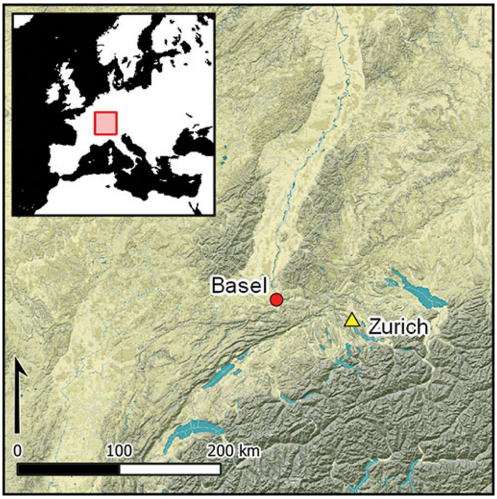
Antiquity 2026 Vol. 100 (410): 500–516
https://doi.org/10.15184/aqy.2026.10297

Research Article

All equal in the face of death? Life histories of confirmed victims of the last plague epidemic in Basel (Switzerland)

Laura Rindlisbacher[1,2], Elias Flatscher[2,3], Claudia Gerling[1,4], Ben Krause-Kyora[5] & Sandra L. Pichler[1]

[1] Integrative Prehistory and Archaeological Sciences, University of Basel, Switzerland
[2] Archäologische Bodenforschung Basel-Stadt (ABBS), Basel, Switzerland
[3] Department of Art History, University of Zurich, Switzerland
[4] Pre- and Protohistoric Archaeology and Archaeology of the Roman Provinces, University of Basel, Switzerland
[5] Institute of Clinical Molecular Biology, Kiel University, Germany
Author for correspondence: Laura Rindlisbacher ✉ lor.rindlisbacher@unibas.ch



The Covid-19 pandemic widened public awareness of the close links between socioeconomic status and resilience in the face of infection, yet this interplay was already well established in archaeological discourse. Here, the authors combine osteoarchaeological, stable isotope and pathogenomic analyses with archival research to explore the formation of multiple, or 'plural', burials at an early hospital in Basel, Switzerland. Identification of a stamped clay pipe, *Yersinia pestis* DNA and a high proportion of subadults link the burials to an outbreak of plague in 1665–1670, while physiological stress, dietary and pathological insights contribute to our understanding of prior experiences affecting differential mortality.

Keywords: Western Europe, Early Modern, epidemic demography, index of skeletal frailty, social inequality, *Yersinia pestis*, child labour

Introduction

While the global population recently had to learn how to navigate a pandemic, epidemics were old—albeit unwelcome—acquaintances for the populace of Early Modern Europe (AD 1500–1750). By this period, the 'plague'—an appellation applied to

Received: 5 November 2024; Revised: 4 August 2025; Accepted: 6 October 2025

numerous infectious diseases but most associated with the *Yersinia pestis* bacterium—had been ravaging the continent regularly for centuries, claiming large numbers of lives (Alfani & Murphy 2017). In recent years, these epidemics have been the subject of archaeo(bio)logical and palaeogenetic studies, from the so-called Justinianic Plague in the sixth century (Keller *et al.* 2019) to the pestilences of the Early Modern period (Eaton *et al.* 2023).

The city of Basel (Switzerland) played an important, though inglorious, role during the various plague epidemics. To secure trade and thus the city's income, the council repeatedly refused to close the city gates, thus facilitating the spread of disease (Hatje 1992: 75–82). Many Early Modern pestilences are presumed to have entered Switzerland via Basel and then continued to Italy along the trade routes (Burghartz 2014). City archives also offer a wealth of historical medical sources on the course of the various epidemics. The city physician Felix Platter (1536–1614), who experienced seven plague epidemics in his lifetime, left a detailed report on the number of deaths and recoveries during the epidemic of 1610/1611, including residential addresses (Lötscher 1987). Records of the city's *Bürgerspital* (municipal hospital), founded prior to 1265 (Flatscher & Rindlisbacher 2021), contain data on sick and deceased persons for each year of operation.

Recent excavations in the centre of Basel uncovered multiple burials from the Early Modern period, including a group of graves with a possible link to the last outbreak of pestilence recorded in Switzerland in 1665–1670 (Flatscher & Rindlisbacher 2021), providing an invaluable opportunity to directly compare osteoarchaeological and archival evidence on the effects of an epidemic on the populace of an Early Modern city. Using the individuals from these graves as a case study and integrating ancient pathogenomic and dietary analyses, we investigate whether socioeconomic status affected mortality during an epidemic.

From monastery to hospital and cemetery

In 2016–2017, excavations in the *Stadtcasino* concert hall uncovered the remains of the so-called *Barfüsserkloster* (Franciscan) monastery, founded in AD 1250 (Bernasconi & Graber 2017). After the Reformation and the resulting abandonment of the complex in 1529, the monastery cloister and the monks' hermitages were repurposed as an early 'asylum' by the neighbouring hospital to house people who—according to the city council and hospital doctors—needed special supervision (Rindlisbacher *et al.* in press), at times also serving as a plague hospital (Roth 2020). The buildings themselves were finally demolished in 1843 (Bernasconi & Graber 2017).

Inside the former cloister garden, the burials of 279 individuals dating to the post-Reformation period were discovered (Figure 1; Flatscher & Rindlisbacher 2021). An older phase of east–west-oriented graves mainly comprised multiple burials (group A). In this phase, the dead were wrapped in shrouds and laid to rest in simple earthen pits, which occasionally yielded components of clothing, knives, sewing rings or needles.

Figure 1. Map of the cemetery at the Basel 'Barfüsser' monastery highlighting burial groups A, B & C; top-right rectangle marks investigated plural burials (figure © Archäologische Bodenforschung Basel-Stadt; figure by P. von Holzen).

A later, north–south-oriented phase comprised both multiple (group B) and single burials (group C). Iron nails in many of the graves give evidence of coffin burials, and there were numerous finds of personal items such as clay pipes, coins and amulets (Flatscher & Rindlisbacher 2021).

Burial activity in this area likely began well before 1600; preliminary numismatic analysis and radiocarbon dates from group B burials place the later phase in the seventeenth and early eighteenth centuries, with a probable interval from 1575 to 1625 separating the phases (Fortunato 2021: 30–32). The differences in orientation and mortuary practice suggest that the burial area underwent changes in utilisation and that at times it may have been used as an epidemic or emergency cemetery, particularly given the presence of graves containing up to seven simultaneously buried individuals. In this article, we focus on a group of these plural burials from group B (for the comprehensive osteological analysis of the Stadtcasino sample see Flatscher and Rindlisbacher (2021) and Rindlisbacher (in press).

Plural burials: graves 229 to 232

The four north–south/south–north oriented graves (nos. 229, 230, 231 and 232) that form the focal case study for this article contained a total of 15 individuals, some of whom were interred in coffins. Located in the northern part of the excavation area, the burials were partially disturbed by the construction of a nineteenth-century cellar (Figure 2). A clay pipe made of white earthenware (type Duco BT2) was found at the hip of individual 229.2 (Figure 3). Traces of soot confirm its use and the pipe maker's stamp on the heel, showing

Figure 2. From left to right, graves 229, 230, 231 and 232 during excavation, upmost layer (figure © Archäologische Bodenforschung Basel-Stadt; photographs by A. Jost).

Figure 3. Clay pipe from grave 229 with pipe maker's stamp attributed to Reichard West (Mannheim, Germany) (figure © Archäologische Bodenforschung Basel-Stadt; photographs by P. Saurbeck, section drawings by E. Flatscher).

a crowned rose and the monogram RW, can be attributed to Reichard West, who was noted as a pipe maker in council minutes from Mannheim (Germany) between 1673 and 1675 and died around 1675/1676 (Flatscher & Rindlisbacher 2024). Reichard's production of clay pipes in Mannheim can be assumed to have started around or after 1650. Due to their fragility, clay pipes have a short lifespan (typically less than three years) and this piece was probably buried with its owner shortly after it was purchased, thus providing both a *terminus post quem* and a *terminus ante quem* for burial 229.2—and by extension burial group 229–232.

The plague in Basel in 1610/1611 and 1667/1668

A qualitative review of historical documents, including the hospital records held in the Basel State Archives (StABS), provides valuable information on the waves of plague that ravaged the city. The records of the *Basler Bürgerspital* bear witness to several epidemics, though some received relatively little attention. The approximate beginning of such an outbreak in 1610 is only noted in a short addition to a register entry dated 22 June: "NB: ungefohrlichen umb dißer Zeit hat die Pest angefangen grassiren" (at about this time, the plague started to spread; StABS Spital V 7.1–4). Subsequently, only a few entries explicitly noted that patients suffered from the plague. Besides a notable increase in mortality, cases of recovery were also recorded. An addendum dated 18 March 1611 notes: "Ungefohrlichen biß an diße obstehende Persohn hat die Pest grassirt, zumaßen die vorbeschribenen Persohnen vast alle es seye dan die anderen Kranckheiten sonders dabey benambst an der pest verstorben [. . .]" (Translated as "Until about [the death of] the person listed above, the plague was raging, to the point that the persons listed previously all died of the plague, unless other illnesses are explicitly noted.") However, plague deaths were still recorded until the summer of 1611.

The *Bürgerspital*'s records of annual expenditure (StABS Spital F 12, Ausgabenbücher) show that there were 10–60 burials in 'ordinary' years in the sixteenth and seventeenth centuries. In contrast, 270 burials were recorded in 1610, and in the autumn and winter of that year frequent entries indicate the simultaneous burial of up to 11 deceased (StABS Spital F 12, Ausgabenbücher, 1610). For the last outbreak of the plague in Basel (1667–1668), a peak of 76 burials was reached in 1667 (StABS Spital F 12, Ausgabenbücher 1667). While multiple sources document a lower mortality rate during this outbreak (Lötscher 1987: 78–74), it should be noted that the *Bürgerspital* accepted only patients with full citizenship status from either the city or the surrounding *Landschaft,* or those who had the financial backing of an employer (Burghartz 2011).

Some sources, however, indicate that domestic servants—even those originating from the *Landschaft*—were expelled from the city if they fell sick (Schluchter 1987). The impact of such social givens must be considered when interpreting the suspected plague victims from group B (see online supplementary material (OSM) section S1).

Methods

Osteological assessment

Biological age, sex and stature were assessed using an established canon of osteological methods (Mitchell & Brickley 2018; see OSM section S2.1). Pathological lesions were recorded qualitatively (Buikstra 2019; see OSM section S2.2), supplemented by an assessment of *spondyloarthrosis deformans*—a degenerative condition that affects the intervertebral joints of the spine—in all age groups. To evaluate these data a modified Index of Skeletal Frailty (ISF; Marklein *et al.* 2016) was employed (see OSM section S2.2). The assembled data were used to generate individual biological profiles, allowing a direct comparison of subadult and adult individuals.

Stable carbon and nitrogen isotope analyses

The analysis of stable isotopes from human skeletal remains can provide information on diet, physiological and health status (Reitsema & Holder 2018). Bone remodels throughout an individual's lifetime, with ribs exhibiting the fastest turnover; these bones therefore provide information about nutrition and physiological stress in the final few years of life (Fahy *et al.* 2017). Stable carbon and nitrogen isotope analyses were carried out on ribs from 11 of the 15 individuals (Table S1). The samples were analysed using the modified Longin method (Doppler *et al.* 2017) on an Integra 2 EA-IRMS (Sercon Ltd, Crewe, UK) at the Aquatic and Isotope Biogeochemistry research unit, University of Basel (see OSM section S2.3).

Detection of ancient pathogens

The study of metagenomes has greatly enhanced our understanding of the presence and impact of pathogens in historical populations. In recent years genomic analysis has provided insights into the spread of *Yersinia pestis* and the evolution of its virulence (Susat *et al.* 2020).

Eleven teeth were sampled from 10 individuals. Ancient DNA (aDNA) was extracted following established protocols, and high-throughput sequencing libraries were prepared (Krause-Kyora *et al.* 2018). All libraries underwent shotgun sequencing on Illumina HiSeq4000 (2×75bp). The resulting pathogenomic sequencing data were analysed to identify sequences specific to *Y. pestis* using the alignment tool MALT (Herbig *et al.* 2016). Additionally, genome-wide data were generated for one of the five positive samples (229.2) to produce in-depth information on the bacterial component. These data were used for phylogenetic classification alongside existing data (228 modern and

38 ancient strains and *Y. pseudotuberculosis*) to calculate a maximum likelihood tree for the Basel strain (Susat *et al.* 2021; see OSM section S2.4).

Results

Demography, stature and health status

The 15 individuals in graves 229–232 range in age from young children to older adults (Table S1). The average age at death among the group is 17.7 years, with the youngest (229.4) having died aged 3–4 years and only four individuals having survived beyond 20 years (Figure 4). Due to the high proportion of subadults, osteological sex assessment was not possible for eight of the 15 individuals (ambiguous: n = 4; indet: n = 4). Of the remainder, five individuals were assigned a male and two a female sex. The stature of three adult individuals with sufficiently preserved longbones varied between 1.55 and 1.68m (Table S1).

Despite the low average age at death, the individuals from this grave group exhibit a large number of pathological conditions (see OSM section S3), including degenerative lesions, which is also reflected in a high average ISF value of 3.3 (n = 10, Table S3.1). Teeth were available for assessment for 11 individuals, all of whom display at least one carious lesion. Of the 310 teeth available, 64 are affected. Caries frequency in the group was 100 per cent, caries intensity 21 per cent. Four individuals (230.2, 230.3, 230.4 & 231.6) suffered from antemortem tooth loss as well as exhibiting active dental abscesses or cysts. Evidence for severe periodontal disease is only observed in the two eldest individuals (230.4 and 231.6). Transverse bands of decreased enamel thickness and/or pitting (enamel hypoplasia) are observable in 11 individuals, with 61 per cent of teeth affected. In addition, two individuals (229.2 & 231.6) show dental wear indicative of habitual use of the teeth as tools.

Only two individuals (231.2, 231.6) have osteological indications of active or chronic infections at the time of death. All individuals, however, show signs of non-specific

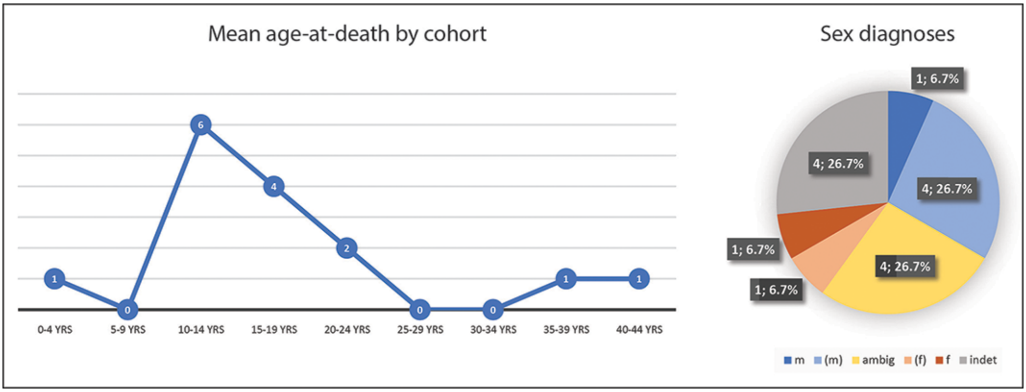


Figure 4. Age and sex assessment of the 15 individuals in grave group 229–232 (sex diagnoses: number of individuals; percentage) (figure by L. Rindlisbacher).

physiological stress, both as acute or chronic processes as well as healed lesions. Seven individuals display porosity of the upper orbits (cribra orbitalia, 2 active) or the femoral neck (cribra femoralis, 3 active).

Spondyloarthrosis deformans occurs in all individuals; those under 15 years of age show light expressions, those between 15 and 25 years old mainly show 'medium' stages. A total of seven traumatic lesions are observed in four individuals, all antemortem healed fractures (of a clavicle, a femur, four ribs and one tooth). Congenital changes were found in two individuals: individual 229.5 exhibits a cleft palate and individual 231.5 shows an idiopathic scoliosis of the thoracic spine.

Nutrition

Stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope data are listed in Table S1. The collagen preservation of all sampled bones met the quality criteria (Ambrose 1990; van Klinken 1999). Variation in isotopic values is small, with most samples (n = 6) clustering between $\delta^{13}C$ -20.3 and -20.0‰ and $\delta^{15}N$ 9.0 and 9.4‰. Mean values of subadults (n = 7) and adults (n = 4) show no significant differences ($\delta^{13}C$ -20.3±0.2‰ versus -20.2±0.1‰ and $\delta^{15}N$ 9.1±0.4‰ versus 9.3±0.3‰). Similarly, no differences were identified between (leaning) male (n = 5; $\delta^{13}C$ -20.2±0.2‰, $\delta^{15}N$ 9.1±0.3‰) and (leaning) female (n = 2; $\delta^{13}C$ -20.3±0.1‰, $\delta^{15}N$ 9.2±0.1‰) individuals (Figure 5).

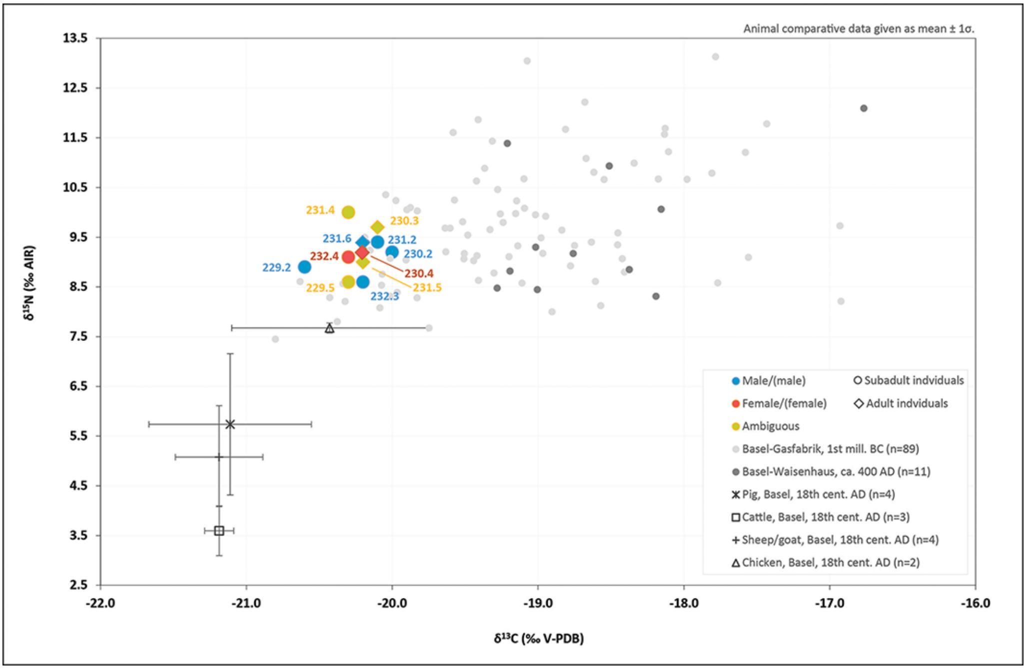


Figure 5. Stable isotope data of the individuals in grave group 229–232. The comparative data are not categorised by age (subadult or adult) (figure by C. Gerling).

Compared with a reference dataset of faunal material from eleventh to thirteenth (Depaermentier *et al.* 2023) and eighteenth century contexts in Basel (Table S4.2), and also incorporating animals and plants from the first century BC Basel-Gasfabrik site (Knipper *et al.* 2017), the Early Modern individuals discussed in this article shared similar diets dominated by C_3 plants and C_3 plant-consuming herbivores, in particular sheep/goat and pig. The low $\delta^{13}C$ values indicate that C_4 plants (such as millet) were consumed only in small quantities, if at all. This contrasts with preceding Late Iron Age (late first century BC) and Late Antique/early medieval (*c.* AD 400) diets, where single individuals with more positive $\delta^{13}C$ values are attested (Knipper *et al.* 2017; Depaermentier *et al.* 2023). The low $\delta^{15}N$ values exclude suckling animals, chicken and salmonids as significant food resources. The Stadtcasino individuals plot at the lower end of the $\delta^{15}N$ distribution for Basel-Gasfabrik (late first century BC) and Basel-Waisenhaus (*c.* 400 AD) (Figure 5), yet these values are still enriched by one trophic level compared with eighteenth-century fauna, indicating the consumption of animal protein.

Pathogen analysis

DNA was successfully isolated and shotgun sequenced from all 11 samples, generating between 8 and 40 million raw reads per sample. Pathogen screening revealed five samples positive for *Y. pestis.* Among the screened samples, four yielded low read counts, ranging from two to 359 reads. In contrast, sample 229.2 exhibited a higher number of pathogen-associated reads (1046, see Table S1) and was submitted for deeper sequencing, resulting in a total of 2 121 086 775 raw reads. The merged dataset was aligned to the *Y. pestis* reference genome (CO92, NC_003143.1), successfully covering 89 per cent of the chromosome and between 81 and 94 per cent of the three plasmids (Table S4.1). Analysis of terminal deamination patterns demonstrates damage profiles characteristic of authentic ancient DNA (see OSM section S2.4).

Comparative analysis with modern and ancient *Y. pestis* strains reveals that the strain in individual 229.2 clusters with strains identified in individuals who died during the plague epidemics in London (1560–1635) and Marseille (1720–1722) (Figure 6). The analysed strain exhibits a marked reduction in coverage within the *pla* gene region (NC_003132.1:6428-8530), which encodes a hypothetical protein possibly involved in regulating transcription, situated on the pPCP1 plasmid. Depletion of the *pla* region has previously been observed in post-Black Death strains (i.e. after 1353) (Susat *et al.* 2020).

Discussion

Osteological evidence for a catastrophic mortality event

The simultaneous burial of several bodies observed in graves 229–232 strongly suggests a significant mortality event. In addition to the high proportion of under-20-year-olds, the number of 12- to 19-year-olds is striking, as this age group shows a low mortality rate in non-catastrophic death samples (Figure 4; Chamberlain 2006). The surplus of

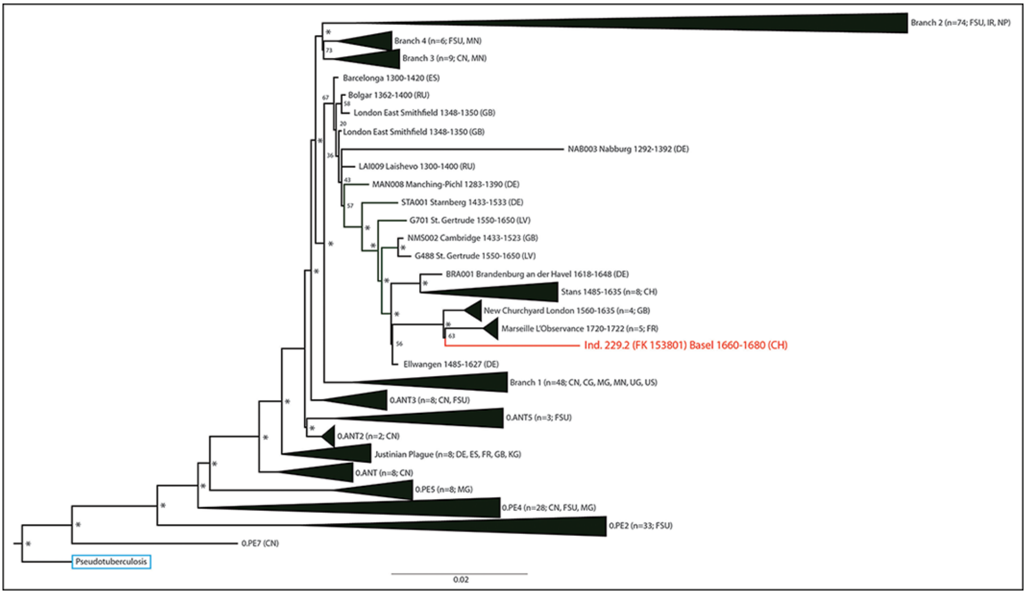


Figure 6. Maximum likelihood tree for the Y. pestis *genome from individual 229.2 (figure by authors).*

males among the individuals for whom osteological sex could be assigned is also conspicuous, although sex is ambiguous or indeterminable for eight individuals, making a conclusive assessment of the sex ratio challenging.

In a burial community representative of natural attrition within a population, a high proportion of subadults, especially of young children below the age of six, is indicative of population growth, as a high birth rate will be accompanied by more child deaths (Bocquet-Appel 2008). In the present case, however, the demographic structure within the grave group does not fit such an explanation. A peak in the mortality of young males is also often associated with warfare (Chamberlain 2006: 123–25) but the absence of perimortem injuries rules out this possibility here. Relatively few pathological lesions were active around the time of death among the investigated group, even compared with other burial communities from this period (e.g. Molleson *et al.* 1993; Ulrich-Bochsler *et al.* 2016). Together with the mortality profile, this observation suggests an epidemic event.

The plague pathogen

The pathogenomic data indicate that at least five individuals from burial group B (one-third) were infected with *Y. pestis* and quite possibly died from the infection. This evidence supports the hypothesis that the former cloister garden was occasionally used as an emergency cemetery, here possibly linked to the last plague outbreak of 1665–1670 in Switzerland. The clay pipe associated with burial 229.2, which also yielded the best preserved *Y. pestis* DNA, supports this temporal link.

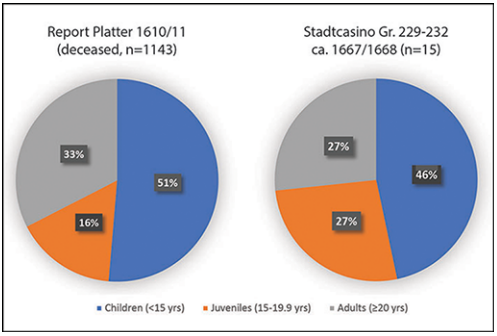


Figure 7. Comparison of the age composition of the Felix Platter data for the 1610/1611 plague and grave group 229–232 (figure by L. Rindlisbacher).

Reconstruction and analysis of the *Y. pestis* genome from burial 229.2 suggests that the bacterium is most closely related to strains obtained from individuals buried in plague contexts in London and Marseille (Spyrou *et al.* 2019). All three strains have a depletion in the *pla* region characteristic of post-Black Death strains (Susat *et al.* 2020). This depletion may have reduced transmission and infection rates, contributing to varied disease outcomes. However, the disease was likely fatal in the five identified cases (229.2, 231.2, 231.4, 231.5, 231.6).

Plague demographics

The low average age at death (17.7 years), the high proportion of non-adult individuals and over-representation of males are all consistent with observations from other plague contexts of the Early Modern period (Kahlow 2007; Castex & Kacki 2016). In a transcription of the report left by town physician Felix Platter, Lötscher (1987) undertook a detailed evaluation of the plague numbers in the five Basel *Vorstädte* (the suburbs surrounding the city centre), distinguishing between men, women, *Jungmänner*, *Döchteren* (both sexes aged 15–20) and children up to the age of 14. At 77 per cent, the high proportion of children who fell ill and died in the *Vorstädte* in 1610/1611 is striking (Table S5.1). Women seem to have had the best chance of surviving infection (approximately 50%), while men showed a lethality rate of 62 per cent. Overall, around 60 per cent of those infected were under 20 years old, and they made up roughly the same proportion of those who died. For the *Jungmänner*, *Döchteren* and children in the Basel suburbs, a lethality rate of around 72 per cent can be observed, while the adults had a lower lethality rate of 54 per cent. These demographic patterns are reflected in the individuals from grave group 229–232 (Figure 7).

Working with an estimated population size of around 12 600 for Basel, a mortality rate of approximately 30 per cent is assumed for the outbreak of 1610/1611, with a morbidity rate of 50 per cent and a lethality rate of 62 per cent (Lötscher 1987: 38). However, this outbreak was particularly severe and no comparable reports are available for the outbreak of 1667/1668. The fact that the death toll at the *Bürgerspital* was relatively low compared with earlier epidemics may be an indication of reduced lethality in this later outbreak. Overall, a particular demographic pattern seems to be associated with the plague in the Early Modern period, not only in Basel but also in various locations in France: an increased mortality of juvenile age groups is observed in the sixteenth and seventeenth centuries compared with outbreaks of the Black Death in the fourteenth century (Castex & Kacki 2016).

Who lives and who dies during plague?

Several plague cemeteries are recorded for Early Modern Basel, including the *Elisabethenfriedhof* (Steiner 2019) but not the site in the former Barfüsser monastery (Roth 2020). Proximity to the hospital does, however, suggest a connection and bioarchaeological characterisation of the sample provides information on the socioeconomic background of the buried individuals (Rindlisbacher *et al.* in press; Rindlisbacher in press).

Use of the ISF enables a comparison of the proportions of different pathological conditions within the burial group without overemphasis of the state of health at the time of death, thus following a life-history approach. Despite the low average age at death, the ISF in the burial group is high; monastic and non-monastic medieval burials from London yield an ISF of 2.09 for 18- to 25-year-olds (Marklein & Crews 2017: tab. 9), while the same age group from the analysed burials have an ISF of 3.67. Due to the canon of characteristics included in the ISF, indices should rise with increasing age as degenerative changes and trauma accumulate over the course of a lifetime. This is true for the analysed individuals from Basel (Figure S3.1) but a diachronic comparison reveals that the Stadtcasino individuals have a higher proportion of enamel hypoplasia, parodontal disease, healed trauma and degenerative processes than the individuals from medieval Britain.

Evidence of non-specific stress in childhood may be seen in the presence of transverse enamel hypoplasia, found in all scored individuals in the Stadtcasino group (Table S3.5). In an Early Modern context (or any setting pre-dating the twentieth century), hypoplasia that formed between 3 and 6 years of age (judged by the position of the band on the tooth crown) are likely social indicators; by this age, children were actively integrated into family work activities and were therefore also exposed to diverse pathogens and stress factors (Röder 2015: 280–81). How early and, above all, how strenuous and what types of work (younger) children performed depended not only on a society's understanding of childhood (Röder 2015) but also on the socioeconomic status of their parents (Lewis 2016: 140). Members of the poorer, lower social classes, in particular, performed physically demanding work (Jütte 2000: 56–57; Redfern 2017: 120) and the resultant strain can manifest in the skeleton both in degenerative lesions and in musculoskeletal stress markers (Vilotte *et al.* 2010). Considering the low individual ages at death observed among the group, the number of individuals showing activity-related degenerative spinal or shoulder lesions is striking (Figure S3.7). A higher percentage of joint and spine lesions are observed in adolescents (aged 14–25 years) from urban areas than from rural contexts in medieval England (Lewis 2016); although individual socioeconomic status is not considered, apprenticeship and work migration may be contributing factors and parallels may be drawn with Early Modern Switzerland (Simon-Muscheid 2010).

Socioeconomic background also dictates access to food and nutrients, which in turn may be inferred from stable isotope data. Although primarily used to provide information on dietary composition (Pollard *et al.* 2023), carbon and nitrogen isotopic ratios can also be influenced by aspects of individual health (Richards & Montgomery 2012;

Reitsema & Holder 2018). Individuals from grave group 229–232 have broadly similar isotopic values but slight outliers may be demonstrative. Individuals 229.5 (cleft palate) and 232.3 have lower $\delta^{15}N$ values; 229.2 (plague, teeth-as-tool use) has a lower $\delta^{13}C$ value; while 231.4 (plague) and 230.3 (inflammation, degenerative lesions) have (slightly) elevated $\delta^{15}N$ values. Except 230.3, all outliers are subadults. In this context, it seems plausible that these differences are disease-related rather than reflecting different diets. Low $\delta^{13}C$ values are, for example, observed in syphilis patients (Olsen *et al.* 2014), and metabolic stress during pregnancy, hunger episodes and inflammatory diseases can lead to fluctuations in $\delta^{15}N$ ratios in body tissues (D'Ortenzio *et al.* 2015; Walter *et al.* 2020).

The ability to recover normal physiological functioning following overexertion or illness is not the same for every individual and this ability is heavily influenced by social status. If a person cannot ensure their basic needs are met without working constantly, healing or recovery is often foregone (Redfern 2017: 77–78). Studies on the modern 'presentism' phenomenon (going to work while sick) identify financial stress as a decisive factor behind this behaviour (Callen *et al.* 2013). From an osteological point of view, this means that people living in precarious circumstances are more likely to experience chronic overexertion and are therefore more likely to show osteological markers of stress. These skeletal manifestations have been linked to socially mediated health inequalities in both modern clinical and archaeological contexts and have in recent years also been the topic of various osteoarchaeological studies (e.g. Larsen 2015; further details in OSM section S5). During the Early Modern period, a large proportion of Basel's population lived under precarious economic conditions, covering a spectrum from low-income work and occasional begging to the most profound poverty (Burghartz 2011).

During a crisis or epidemic, social status has a decisive influence on mortality, with access to essential goods or institutions and overall social cohesion determining the probability with which groups of people fall ill, need care or die (DeWitte 2020; Galanaud *et al.* 2020). The degree of physiological, physical or dietary stress experienced during childhood, often directly related to social status, also influences vulnerability during an epidemic (Primeau *et al.* 2018). As is evident from plague burials in Basel and elsewhere, the intersectionality influencing the social status—and related social participation (Rindlisbacher in press)—of the members of the middle and lower classes affected the health status of individuals in many ways, including their susceptibility and resilience to the plague.

In the light of these various observations drawn from the different analyses the interpretation of burial group 229–232 as lower-class individuals, maybe even some non-citizens (see S1), seems highly plausible. Furthermore, such observations hold true for the other individuals from the Stadtcasino site (for the comprehensive study see Rindlisbacher in press). These patterns underline the influence of health inequalities which often intensify in times of crisis in Basel and elsewhere.

Conclusion

Detection of the plague pathogen *Yersinia pestis* in grave group 229–232 from the Stadtcasino site in Basel not only corroborates the catastrophic mortality profile of the 15 buried individuals, but the recovery of a stamped clay pipe from grave 229 permits both the precise dating of the burials and the identification of the specific bacterial strain responsible for the 1667/1668 Basel outbreak. Combined with the rich historical sources on plague epidemics in Basel and patient records from the *Bürgerspital*, the Stadtcasino site offers an extraordinary opportunity to examine the differential mortality of one of the later plague outbreaks. The recent Covid-19 pandemic demonstrated how deeply socioeconomic status influences the vulnerability of specific social groups, but this is not a new phenomenon; this article adds another case study underlining the opportunities for gaining differentiated sociohistorical insights offered by the implementation of interdisciplinary approaches in archaeology. Comparison of the different burial groups across the wider Stadtcasino site will highlight the diversity of the experiences of groups often monolithically addressed as the 'lower classes' (Rindlisbacher in press) and thus enable new and more nuanced narratives of Early Modern Basel and life during a historic pandemic.

Acknowledgements

The authors would like to thank Peter Roth (historical analysis, transcriptions), Rahel Ackermann (numismatics), Norbert Spichtig, Marco Bernasconi (project management ABBS), Philippe Saurbeck, Peter von Holzen (photography and illustrations), the whole team of the 2016–2017 excavations, Moritz Lehmann and Thomas Kuhn (MS analysis), Barbara Stopp (animal species determination) and Julian Susat (aDNA lab work) for their contributions.

Funding statement

This project was supported by the Archäologische Bodenforschung Basel-Stadt, the Freiwillige Akademische Gesellschaft and the Department of Environmental Sciences, University of Basel.

Online supplementary material (OSM)

To view supplementary material for this article, please visit https://doi.org/10.15184/aqy.2026.10297 and select the supplementary materials tab.

Author Contributions: using CRediT categories

Laura Rindlisbacher: Conceptualization-Lead, Data curation-Equal, Formal analysis-Equal, Funding acquisition-Lead, Investigation-Equal, Methodology-Equal, Visualization-Equal, Writing - original draft-Lead. **Elias Flatscher:** Formal analysis-Equal, Investigation-Equal, Visualization-Equal, Writing - original draft-Equal. **Claudia Gerling:** Formal analysis-Equal, Investigation-Equal, Methodology-Equal, Visualization-Equal, Writing - original draft-Supporting. **Ben Krause-Kyora:** Data curation-Equal, Formal analysis-Equal, Methodology-Equal, Visualization-Equal, Writing - original draft-Supporting. **Sandra L. Pichler:** Conceptualization-Lead, Funding acquisition-Lead, Investigation-Equal, Methodology-Equal, Project administration-Lead, Supervision-Lead, Writing - original draft-Equal.

References

ALFANI, G. & T.E. MURPHY. 2017. Plague and lethal epidemics in the pre-industrial world. *Journal of Economic History* 77: 314–43. https://doi.org/10.1017/S0022050717000092

AMBROSE, S.H. 1990. Preparation and characterization of bone and tooth collagen for isotopic analysis. *Journal of Archaeological Science* 17: 431–51. https://doi.org/10.1016/0305-4403(90)90007-R

BERNASCONI, M. & S. GRABER. 2017. Vom mittelalterlichen Kloster zum modernen Konzertgebäude. 800 Jahre Stadtentwicklung: Archäologische Ausgrabungen im Musiksaal des Basler Stadtcasinos. *Jahresbericht der Archäologischen Bodenforschung Basel-Stadt* 2016: 66–101. https://doi.org/10.12685/jbab.2016.67-101

BOCQUET-APPEL, J.-P. 2008. *La paléodémographie. 99,99% de l'histoire démographique des hommes ou la démographie de la Préhistoire*. Paris: Errance.

BUIKSTRA, J.E. (ed.) 2019. *Ortner's identification of pathological conditions in human skeletal remains*. London: Academic Press.

BURGHARTZ, S. 2011. Im Angesicht der Armut. Ordnung, Regulierung und Fürsorge im 16. und 17. Jahrhundert, in J. Mooser & S. Wenger (ed.) *Armut und Fürsorge in Basel. Armutspolitik vom 13. Jahrhundert bis heute*: 49–72. Basel: Merian.

– 2014. Vom offenen Bündnissystem zur selbstbewussten Eidgenossenschaft: das 14. und 15. Jahrhundert, in S. Arlettaz & G. Kreis (ed.) *Die Geschichte der Schweiz*: 136–83. Basel: Schwabe.

CALLEN, B.L., L.C. LINDLEY & V.P. NIEDERHAUSER. 2013. Health risk factors associated with presenteeism in the workplace. *Journal of Occupational and Environmental Medicine* 55: 1312–17. https://doi.org/10.1097/JOM.0b013e3182a200f4

CASTEX, D. & S. KACKI. 2016. Demographic patterns distinctive of epidemic cemeteries in archaeological samples. *Microbiology Spectrum* 4. https://doi.org/10.1128/microbiolspec.poh-0015-2015

CHAMBERLAIN, A. 2006. *Demography in archaeology*. Cambridge: Cambridge University Press.

DEPAERMENTIER, M.L.C. *et al.* 2023. Bioarchaeological analyses reveal long-lasting continuity at the periphery of the Late Antique Roman Empire. *iScience* 26. https://doi.org/10.1016/j.isci.2023.107034

DEWITTE, S.N. 2020. Social inequality in times of pandemics. *Anthropology News* May/June. https://doi.org/10.1111/AN.1437.

DOPPLER, T. *et al.* 2017. Landscape opening and herding strategies: carbon isotope analyses of herbivore bone collagen from the Neolithic and Bronze Age lakeshore site of Zurich-Mozartstrasse, Switzerland. *Quaternary International* 436: 18–28. https://doi.org/10.1016/j.quaint.2015.09.007

D'ORTENZIO, L., M. BRICKLEY, H. SCHWARCZ & T. PROWSE. 2015. You are not what you eat during physiological stress: isotopic evaluation of human hair. *American Journal of Physical Anthropology* 157: 374–88. https://doi.org/10.1002/ajpa.22722

EATON, K. *et al.* 2023. Emergence, continuity, and evolution of *Yersinia pestis* throughout medieval and early modern Denmark. *Current Biology* 33: 1147–52. https://doi.org/10.1016/j.cub.2023.01.064

FAHY, G.E., C. DETER, R. PITFIELD, J.J. MISZKIEWICZ & P. MAHONEY. 2017. Bone deep: variation in stable isotope ratios and histomorphometric measurements of bone remodelling within adult humans. *Journal of Archaeological Science* 87: 10–16. https://doi.org/10.1016/j.jas.2017.09.009

FLATSCHER, E. & L. RINDLISBACHER. 2021. «unndt wiederumb curiert undt gesund hinauß»? Ein interdisziplinärer Blick auf einen Friedhof des 17. Jahrhunderts im Basler Almosen, in D. Schneller & G. Lassau (ed.) *Basel und der Dreissigjährige Krieg*.

Zuwanderung, Zerstörung, Festungsbau und neue Konzepte im Städtebau und Bauwesen Europas vom 16. bis zum 18. Jahrhundert: 89–105. Basel: Kanton Basel-Stadt.

– 2024. "Hohle" Kurfürsten und eine "echte" Pestpfeife: Keramische Funde als Hilfe bei der absolutchronologischen Datierung von Gräbern am Beispiel der Grabung Basel Stadtcasino. *Bulletin Keramikfreunde der Schweiz* 103: 31–38.

FORTUNATO, M.A. 2021. Kloster und Almosen - Rippen zweierlei Art: Vergleich zweier Probenaufbereitungsmethoden für C14-Analysen an spätmittelalterlichen bis frühneuzeitlichen Bestattungen aus dem Areal des ehemaligen Barfüsserklosters in Basel. Unpublished BSc dissertation, University of Zürich.

GALANAUD, P., A. GALANAUD, P. GIRAUDOUX & H. LABESSE. 2020. Mortality and demographic recovery in early post-black death epidemics: role of recent emigrants in medieval Dijon. *PLoS ONE* 15. https://doi.org/10.1371/journal.pone.0226420

HATJE, F. 1992. *Leben und Sterben im Zeitalter der Pest. Basel im 15.-17. Jh*. Basel: Helbing & Lichtenhahn.

HERBIG, A., F. MAIXNER, K.I. BOS, A. ZINK, J. KRAUSE & D.H. HUSON. 2016. MALT: Fast alignment and analysis of metagenomic DNA sequence data applied to the Tyrolean Iceman. *bioRxiv.* Published online 27 April 2016. https://doi.org/10.1101/050559

JÜTTE, R. 2000. *Arme, Bettler, Beutelschneider: eine Sozialgeschichte der Armut in der Frühen Neuzeit*. Weimar: Böhlau.

KAHLOW, S. 2007. Die Pest als Interpretationsproblem mittelalterlicher und frühneuzeitlicher Massengräber. *Archäologische Informationen* 30: 97–104.

KELLER, M. *et al.* 2019. Ancient *Yersinia pestis* genomes from across Western Europe reveal early diversification during the First Pandemic (541–750). *Proceedings of the National Academy of Sciences USA* 116: 12363–72. https://doi.org/10.1073/pnas.1820447116

KNIPPER, C. *et al.* 2017. What is on the menu in a Celtic town? Iron Age diet reconstructed at Basel-Gasfabrik, Switzerland. *Archaeological and Anthropological Sciences* 9: 1307–1326. https://doi.org/10.1007/s12520-016-0362-8

KRAUSE-KYORA, B. *et al.* 2018. Ancient DNA study reveals HLA susceptibility locus for leprosy in medieval Europeans. *Nature Communications* 9. https://doi.org/10.1038/s41467-018-03857-x

LARSEN, C.S. 2015. *Bioarchaeology: interpreting behavior from the human skeleton*. Cambridge: Cambridge University Press.

LEWIS, M. 2016. Work and the adolescent in medieval England AD 900–1550: the osteological evidence. *Medieval Archaeology* 60: 138–71. https://doi.org/10.1080/00766097.2016.1147787

LÖTSCHER, V. 1987. *Felix Platter. Beschreibung der Stadt Basel 1610 und Pestbericht 1610/11*. Basel: Schwabe.

MARKLEIN, K.E. & D.E. CREWS. 2017. Frail or hale: skeletal frailty indices in medieval London skeletons. *PLoS ONE* 12. https://doi.org/10.1371/journal.pone.0176025

MARKLEIN, K., R. LEAHY & D. CREWS. 2016. In sickness and in death: assessing frailty in human skeletal remains. *American Journal of Physical Anthropology* 161: 208–225. https://doi.org/10.1002/ajpa.23019

MITCHELL, P.D. & M. BRICKLEY. 2018. *Updated guidelines to the standards for recording human remains*. Reading: Chartered Institute for Archaeologists.

MOLLESON, T., M. COX, A.H. WALDRON & D.K. WHITTAKER. 1993. *The middling sort. The Spitalfields Project vol 2: the anthropology*. York: Council for British Archaeology.

OLSEN, K.C., C.D. WHITE, F.J. LONGSTAFFE, K. VON HEYKING, G. MCGLYNN, G. GRUPE & F.J. RÜHLI. 2014. Intraskeletal isotopic compositions ($\delta^{13}C$, $\delta^{15}N$) of bone collagen: nonpathological and pathological variation. *American Journal of Physical Anthropology* 153: 598–604. https://doi.org/10.1002/ajpa.22459

POLLARD, A.M., R.A. ARMITAGE & C.A. MAKAREWICZ. 2023 *Handbook of archaeological sciences*. Second edition. Hoboken (NJ): Wiley.

PRIMEAU, C., P. HOMØE & N. LYNNERUP. 2018. Childhood health as reflected in adult urban and rural samples from medieval Denmark. *HOMO* 69: 6–16. https://doi.org/10.1016/j.jchb.2018.03.004

REDFERN, R.C. 2017. *Injury and trauma in bioarchaeology: interpreting violence in past lives*. Cambridge: Cambridge University Press.

REITSEMA, L.J. & S. HOLDER. 2018. Stable isotope analysis and the study of human stress, disease, and nutrition. *Bioarchaeology International* 2: 63–74. https://doi.org/10.5744/bi.2018.1018

RICHARDS, M.P. & J. MONTGOMERY. 2012 Isotope analysis and paleopathology: a short review and future developments, in: J.E. Buikstra & C.A. Roberts (ed.) *The global history of paleopathology: pioneers and prospects*: 718–21. Oxford: Oxford University Press. https://doi.org/10.1093/acprof:osobl/9780195389807.003.0072

RINDLISBACHER, L. In press. Feine Unterschiede. Einblicke in die Lebensbedingungen der mittleren und niederen Stände des frühneuzeitlichen Basels, in Materialhefte zur Archäologie in Basel 33. Basel: Archäologische Bodenforschung Basel-Stadt.

RINDLISBACHER, L., E. FLATSCHER & S.L. PICHLER. In press. "Eine Totenhalle für Lebendige?": ein Blick auf die Lebensbedingungen im frühneuzeitlichen Basel anhand des Bestattungskollektivs aus dem Kreuzgarten des Basler Barfüsserklosters, in A. Veling, A. Lätzer-Lasar, S. Schreiber & P. Tollkühn (ed.) *(Un)Sichtbarkeit in der Archäologie*. Heidelberg: Propylaeum.

RÖDER, B. 2015. Kinderarbeit heute - Perspektiven für die Ur- und Frühgeschichte, in R. Kory & R. Masanz (ed.) *Lebenswelten von Kindern und Frauen in der Vormoderne - Archäologische und anthropologische Forschungen in memoriam Brigitte Lohrke*: 275–98. Berlin: Curach Bhán.

ROTH, P. 2020. Das Almosen im Klosterkreuzgang, in Archäologische Bodenforschung des Kantons Basel-Stadt (ed.) *1000 jahre Basler Geschichte*: 94–100. Basel: Merian.

SCHLUCHTER, A. 1987. Zur politischen Ungleichheit vor dem Tode: Standesbürger und Untertanen während der Basler Pest von 1667/68. *Basler Zeitschrift für Geschichte und Altertumskunde* 87: 55–70.

SIMON-MUSCHEID, K. 2010. Gesellen, in *Historisches Lexikon der Schweiz*. Available at: https://hls-dhs-dss.ch/de/articles/016371/2010-11-11/ (accessed 2 May 2024).

SPYROU, M.A. *et al.* 2019. Phylogeography of the second plague pandemic revealed through analysis of historical *Yersinia pestis* genomes. *Nature Communications* 10. https://doi.org/10.1038/s41467-019-12154-0

STEINER, S. 2019. 2017/35. Elisabethenstrasse (A). *Jahresbericht der Archäologischen Bodenforschung Basel-Stadt* 2018: 54–55.

SUSAT, J., J.H. BONCZAROWSKA, E. PĒTERSONE-GORDINA, A. IMMEL, A. NEBEL, G. GERHARDS & B. KRAUSE-KYORA. 2020. *Yersinia pestis* strains from Latvia show depletion of the *pla* virulence gene at the end of the second plague pandemic. *Scientific Reports* 10. https://doi.org/10.1038/s41598-020-71530-9

SUSAT, J. *et al.* 2021. A 5,000-year-old hunter-gatherer already plagued by *Yersinia pestis*. *Cell Reports* 35. https://doi.org/10.1016/j.celrep.2021.109278

ULRICH-BOCHSLER, S., C. COOPER & A. BAERISWYL. 2016. Karies, Knochenbrüche, Infektionen: zwei stadtbernische Friedhöfe des 18. Jahrhunderts als archäologische Quelle. *Berner Zeitschrift für Geschichte* 78: 3–39.

VAN KLINKEN, G.J. 1999. Bone collagen quality indicators for palaeodietary and radiocarbon measurements. *Journal of Archaeological Science* 26: 687–95. https://doi.org/10.1006/jasc.1998.0385

VILOTTE, S., S.E. CHURCHILL, O. DUTOUR & D. HENRY-GAMBIER. 2010. Subsistence activities and the sexual division of labor in the European Upper Paleolithic and Mesolithic: evidence from upper limb enthesopathies. *Journal of Human Evolution* 59: 35–43. https://doi.org/10.1016/j.jhevol.2010.02.001

WALTER, B.S., S.N. DEWITTE, T. DUPRAS & J. BEAUMONT. 2020. Assessment of nutritional stress in famine burials using stable isotope analysis. *American Journal of Physical Anthropology* 172: 214–226. https://doi.org/10.1002/ajpa.24054