Growing up in the suburbs: growth faltering and disease burden in the children from 16th to 18th century Tallinn, Estonia

Article

Accepted Version

To link to this article DOI: http://dx.doi.org/10.1002/oa.3270

Publisher: Wiley

Growing up in the suburbs: growth faltering and disease burden in the children from 16th to 18th century Tallinn, Estonia

Linda Vilumets[1], Ülle Aguraiuja-Lätti[2], Mary Lewis[3]

[1]Department of Archaeology, Institute of History and Archaeology, University of Tartu, Tartu, Estonia
[2] Archaeological Research Collection, Tallinn University, Tallinn, Estonia. Email: uagura@tlu.ee

[3]Department of Archaeology, University of Reading, Reading, United Kingdom. Email: m.e.lewis@reading.ac.uk

Address for correspondence
Linda Vilumets, Department of Archaeology, Institute of History and Archaeology, University of Tartu, Jakobi 2, 51014, Tartu, Estonia. Email: linda.vilumets@ut.ee

ABSTRACT

This study presents the results of the first large scale study of children from Early Modern Northern Estonia. A total of 191 non-adults (<17 years) from the 16th–18th century Tõnismägi cemetery in the suburbs of Tallinn, were analysed to gain a better understanding about the health and living environment of these low-status children. This was achieved through growth analysis and palaeopathological investigation of metabolic and respiratory diseases such as scurvy, vitamin D deficiency and tuberculosis. Growth disruption was shown to be the most severe among non-adults aged between four to nine years, and comparable to children living in post-medieval London. It is unlikely that the children from Tallinn would have experienced the same level of industrial hazards as those in London, but poor socioeconomic status, an impoverished diet and unsanitary living conditions in the suburbs had a detrimental effect on the growth of these non-adults. This was supported by a statistically significant correlation between growth faltering and respiratory infections, and evidence for scurvy in 40% of the infants (n=30). The most likely cause was early weaning and a diet devoid of vitamin C, induced by poverty and cultural practices. The prevalence of rickets was much lower when compared with other post-medieval populations in Europe at just 1.2%. This suggest that children living in Tallinn were not deprived of sunlight and may have had access to more green spaces.

Keywords: non-adult, palaeopathology, tuberculosis, scurvy, Early Modern Period

1. INTRODUCTION

Analysing archaeological skeletal remains of non-adults provides a unique insight into the health and living conditions of the youngest and frailest members of society (Lewis, 2017). Growth faltering, where a child's height falls below that of their peers, is considered one of the best indicators of failure to adapt to the environment today, and it has a direct relationship with socio-economic status, inadequate nutrition, and chronic infection (Bogin, 2021; Crooks, 1999; Norgan et al, 2012; Schell & Rousham, 2022). In bioarchaeology, combining growth faltering in child skeletal remains with evidence for physiological stress, metabolic and respiratory conditions provides direct insight into the childhood living environment. Such an approach has proven fruitful in studies focusing on the detrimental effects of urbanisation and industrialisation on different social groups in medieval and post-medieval England (Lewis, 2002; Newman & Gowland, 2017; Gowland et al., 2018; Ives & Humphrey, 2020), and structural violence of enslaved children in post-medieval Portugal (Cardoso et al., 2019). Past childhood growth studies from other parts of Europe and globally, are less common, but remain an important tool for investigating marginalised, lower social class individuals, who are poorly represented in historical sources. In particular, comprehensive and hypothesis driven research into the past health of children living in Estonia is rare, despite historical data concerning their mortality rates, education and health, and archaeological reports on their skeletal remains (e.g. Malve et al., 2020; Pullat, 1992; Põltsam-Jürjo, 2017). Interest in child bioarchaeology is emerging however, with a recent case study focusing on 43 fetal and perinatal remains from medieval Tartu (Morrone et al. 2021), and infant feeding practices in 176 non-adult individuals from medieval and early modern Livonia, in Southern Estonia (Morrone et al. 2023).

The current study aims to advance this discourse, focusing on 191 non-adults (under 17 years), from the 16th–18th century Tõnismägi cemetery in Tallinn, Northern Estonia. Tõnismägi cemetery served as a suburban burial site for individuals of low socioeconomic status (DCRBMD, 1724–1758; Malve, 2018). Early modern Estonia was characterised by numerous famines, pandemics and military conflicts (Palli, 1996; 1997), all of which would have influenced the lived experience of children in this poor suburban community. An assessment of the morbidity (growth, exposure to stress and disease) and mortality of the Tõnismägi children represents the first large-scale palaeopathological study of non-adults from Estonia and by extension, allows us to better understand the overall living conditions faced by the poor inhabitants of Tallinn. This study presents a particular opportunity to compare osteological and palaeopathological data with contemporaneous historical documents providing a valuable framework for interpreting the bioarchaeological evidence.

2. MATERIALS AND METHODS

2.1 Historical background

Since the Estonian medieval period (AD 1200–1550), Tallinn had been one of the largest towns on the eastern Baltic shore, with an economy mostly based on trade and handicrafts (Mäeorg & Maiste, 2019; Vinnal, 2019). Between the 16th to 18th centuries, the way of life of the population generally remained the same, with greater changes in economy and large industries only emerging in the latter half of the 19th century (Vinnal, 2019). The population fluctuated, depleting as the result of war, famine, and epidemics, and increasing mostly through migration from rural areas, with the number of inhabitants estimated to have been around 7000 to 12,000 (Küng, 2019b). A large proportion of these residents lived outside the town walls. These people were mostly low status ethnic Estonians, and to a lesser extent Swedes, Finns and other migrants who were collectively known as "un-Deutch" to differentiate them from higher social class individuals of German origin (the "Deutch"). The un-Deutch usually only had access to low status, low-paying jobs (Küng, 2019a; Põltsam-Jürjo, 2009).

The suburbs mostly comprised small wooden houses without proper ventilation, situated among limestone or gravel streets, where animals often roamed freely. Despite the urban location, community pastures, fishponds, and gardens allowed inhabitants access to locally grown fruits and vegetables (Kröönström & Põltsam-Jürjo, 2019bc; Orro, 2019ab). Bread, meat, and fish were the main dietary staples across the social strata, with rye bread being a particularly important food source for the lower classes (Pullat, 2014; Põltsam-Jürjo, 2012). Fish was widely consumed among the poor, as it was usually more affordable than meat (Aguraiuja-Lätti & Lõugas, 2019; Põltsam-Jürjo, 2018a). However, many individuals may have been regularly malnourished as the result of the numerous crop failures leading to famine, documented for the period (Kröönström & Põltsam-Jürjo, 2019a; Seppel, 2014ab). Contaminated water supplies were also problem, and written records refer to frequent disease epidemics such as measles, smallpox, typhoid, and scarlet fever, as well the presence of tuberculosis (Bluhm, 1790; Kröönström & Põltsam-Jürjo, 2019b; Rootsmäe, 1987).

2.2 Tõnismägi cemetery

Tõnismägi cemetery was in use between c. AD 1550–1748 and catered for the individuals who lived in the suburbs of Tallinn (von Hansen, 1885; Malve, 2018; Sokolovski & Jaanits, 2003). A partial record of who was buried there is available through the Dome Church Registry of Births, Marriages and Deaths (DCRBMD) dated between AD 1724–1758, which shows that at least third of the deceased were residents of the Dome Church hospital (founded in 1655), which also acted as a poorhouse (Gustavson, 1969). The 191 non-adults in this study were unearthed between 2016 and 2017, when archaeological rescue excavations recovered about 525 *in situ* burials (Bernotas et al., 2017; Malve, 2018). The majority of the deceased were interred in single graves, with the exception of a few adult-child 'double burials' where the casket of a child was placed on the legs of the adult in the same grave cut. The cemetery has been interpreted as a Christian burial ground, and probably reflects the normal attritional mortality rate for the period (Malve, 2018).

2.3 Methods

2.3.1 Age estimation

A mean age-at-death was estimated based on dental development of the mandibular teeth following the method by Moorrees et al. (1963 ab), and tabulated by Smith (1991) to allow growth profiles to be constructed. For individuals where only maxillary teeth survived, the atlas developed by AlQahtani and colleagues (2010) was used. In the absence of teeth, age was established based on epiphyseal fusion (Schaefer et al., 2009) to place non-adults into broader age categories. The gestational age of perinates was assessed using regression equations based on diaphyseal lengths published by Scheuer et al. (1980) as similar data for Estonian populations are not available. For one perinate, without long bones, age was established from pars basilaris and pars lateralis following Cunningham et al. (2016: 64–65). The individuals were then divided into eight age groups: perinate, 0.0–1.0 years, 1.1–2.5 years, 2.6–6.5 years, 6.6–10.5 years, 10.6–14.5 years and 14.6–17.0 years. These age categories do not indicate a cultural age but correlate with important biological stages of childhood: perinatal, infant, young and older children, early and later adolescents. The cut-off point of 17 years was chosen, because by that age most of the lower long bones have completed growth (Schaefer et al., 2009), and it allows for comparisons with other child health and growth studies that have the same cut-off point. Poorly preserved skeletal remains that could not be provided with a specific age were classed as 'non-adult'.

2.3.2 Longitudinal growth

Growth faltering was assessed for 71 individuals whose dental mean age could be established following Moorrees et al. (1963 ab) were placed into one-year age categories. Maximum diaphyseal lengths (in mm) were recorded for the humerus, radius, ulna, femur and tibia. Lower limb bones are considered to be the most sensitive to environmental stress (Pomeroy et al., 2012) and therefore the most suitable for growth studies. Bones of the upper extremities were also included to increase sample size. Measurements were taken from the left side, but in cases of poor preservation or complete absence, bones from the right side were used. Long bones with evident pathology were omitted from growth analysis.

To assess the degree of growth faltering among the Tõnismägi sample, z-scores were calculated following the method described by Cardoso and Garcia (2009), with data derived from Maresh's (1970) Denver Growth Study, updated by Spake and Cardoso (2021). These data provided a reference point for the growth expected in modern, living and healthy children, or 'survivors'. To calculate z-score values, the age specific mean value provided by Maresh's data was subtracted from the diaphyseal length for each child in the Tõnismägi sample, and the result was divided by the age specific Maresh standard deviation. Mean z-scores of less than -0.1 indicate negative deviation from modern healthy children. According to the World Health Organisation (2008), z-score values below -2.0 reflect growth faltering, however, due to the small sample, only z-score values below -3.0 were considered to display reliable evidence of growth deficit at Tõnismägi. Although Maresh (1970) provides growth data for children up to 12 years of age, only non-adults aged 0–9 years from Tõnismägi were preserved well-enough to be included.

To date, there are no comparable growth studies available for archaeological non-adults from Estonia or from the other Baltic states, rather research has focused on adult stature reconstruction (Allmäe, 1997; 1998; Jankauskas, 1992; Šereikienė & Jankauskas, 2002; 2004). Therefore, the results were compared against growth data obtained from later medieval and post-medieval children from England. The later medieval sample comprises 98 individuals (0–9 years) from St. Helen-on-the-Walls in York (AD 1100–1550), a poor parish cemetery, and later burials from St James and Mary Magdelene, on the outskirts of Chichester (AD 1100-1530) (Dawes & Magilton, 1980; Lewis, 2008). Data corresponding to the industrial period (18^{th}–19^{th} century) were derived from 92 individuals from the burial grounds of St. Brides Lower and Cross Bones in London, available on the Wellcome Osteological Research Database (WORD, 2021ab). Although none of these samples perfectly correspond to the time period Tõnismägi cemetery was in use, they represent children of low socioeconomic status exposed to similar environmental conditions. The post-medieval children act as a good reference sample for those with severe growth faltering (Hodson & Gowland, 2019; Newman & Gowland, 2017). In the final analysis, age categories were pooled into three groups (0–1 year, 2–3 years, 4–9 years) due to the uneven distribution of individuals between the datasets, and to increase sample size for the older age groups. Growth profiles were conducted to further illustrate the differences between the populations and on an individual level for Tõnismägi sample.

2.3.3 Palaeopathological analysis

The presence of vitamin C deficiency (scurvy) and vitamin D deficiency (rickets and osteomalacia) was determined following the criteria outlined in Brickley et al. (2020). The presence of widespread 'diagnostic' features (e.g. abnormal cortical porosity on the external surface of the greater wing of sphenoid and periosteal new bone formation (PNBF) on the roof of the orbit) alongside other 'suggestive' features (as per Snoddy et al., 2018) resulted in a scurvy diagnosis, whereas individuals who displayed a more limited spread and severity of the lesions (e.g. PNBF around foramen rotundum and on the lesser wings of sphenoid, and endocranial lesions) were placed into the category of 'possible' scurvy. Individuals who only displayed mild lesions on a single bone were not included. Vitamin D deficiency was regarded 'active' when porosity on the growth plates, cupping and/or fraying of the epiphysis and on costochondral junctions of the ribs was observed. Bones with bowing deformities that may represent a 'healed' disease state were radiographed for signs like cortical thickening and buttressing to establish whether it could have been the result of vitamin D deficiency (Brickley et al., 2020). When the specific nature and distribution of lesions combined with poor preservation of the skeleton made it impossible to distinguish between rickets and scurvy, the pathology was categorised as a general metabolic disease. Since no skeletal lesions are pathognomonic to tuberculosis (TB) (Wilbur et al., 2009), cases of possible TB and its differential diagnosis were based on descriptions outlined by Lewis (2018) and Roberts and Buikstra (2019). Individuals who displayed new bone formation on the visceral surface of the ribs only, were categorised as having an unspecified respiratory infection (Santos & Roberts, 2001; Roberts & Buikstra, 2019).

2.3.4 Statistical analysis

Statistical tests were performed using IBM SPSS Statistics 29.0.0.0. A non-parametric Kruskal–Wallis H-test was carried out to determine whether there was a significant difference between growth faltering among Tõnismägi and the two other datasets. The rejection of the null hypothesis for the Kruskal–Wallis test was automatically followed by a post hoc analysis using Dunn's (1964) procedure with a Bonferroni correction for multiple comparisons. Chi-square tests were conducted to determine whether there was a statistical correlation between growth faltering and a specific pathology.

3 RESULTS

Table 1 summarises the age-at-death profile of the Tõnismägi cemetery sample. The majority of children were under the age of 6.5 years (n=116, 60.7%) with equal numbers of infants and children under the age of 2.5 years (n=38) (Fig. 1). Adolescents were the least represented in the study sample.

Table 1. *Age-at-death profile of the Tõnismägi sample.*

Age category (years)	n	%
Perinate	17	8.9
0.0–1.0	38	19.9
1.1–2.5	38	19.9
2.6–6.5	23	12.0
6.6–10.5	15	7.9
10.6–14.5	8	4.2
14.6–17.0	6	3.1
Non-adult	46	24.1
Total	**191**	**100**

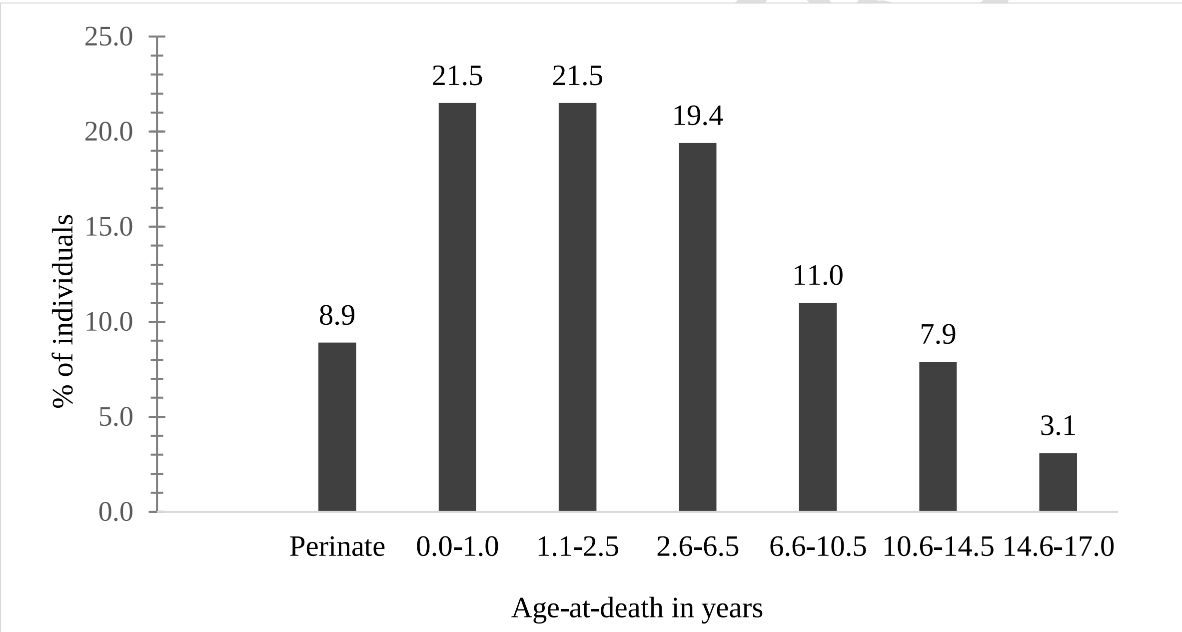


Figure 1. *Age-at-death distribution for the children at Tõnismägi.*

Mean diaphyseal lengths for individuals aged 0–9 years (Table 2) were used to calculate z-scores for each skeletal element (humerus, ulna, radius, femur, tibia) by yearly increments (Table 3). Growth faltering (i.e. z-score below -3.0) was evident in 35.2% (n=25) of Tõnismägi children, with 11/25 (44%) displaying growth disruption on three or more bones. The mean z-scores for Tõnismägi were compared with the children from later medieval and post-medieval (industrial) England, and divided into three age groups (Table 4).

Table 2. *Mean diaphyseal lengths for children in Tõnismägi and England, by mean dental age.*

Sample/age group	Humerus		Ulna		Radius		Femur		Tibia	
	n	**Mean**	**n**	**Mean**	**n**	**Mean**	**n**	**Mean**	**n**	**Mean**
Tõnismägi										
0 years	19	69.28	9	63.29	14	54.75	15	80.99	9	66.59
1 year	13	105.85	7	87.24	6	78.11	5	123.50	1	108.52
2 years	9	122.68	6	98.48	7	90.29	2	159.00	3	126.17
3 years	6	139.92	4	116.13	5	105.40	4	177.00	2	136.25
4 years	1	144.00	1	117.00	2	108.25	2	183.50	1	142.50
5 years	3	153.00	2	130.25	2	116.75	3	204.83	1	153.50
6 years	3	167.67	3	141.00	3	128.50	2	234.50	1	177.50
7 years	3	190.17	2	154.25	2	139.00	3	257.17	4	201.75
8 years	3	194.67	2	164.75	3	140.50	1	220.50	1	215.00
9 years	2	211.00	1	168.50	1	146.50	1	290.00	1	229.00
Industrial period England										
0 years	3	71.03	1	61.10	1	53.00	1	100.80	1	83.20
1 year	26	98.98	18	83.76	21	75.16	21	130.21	9	112.18
2 years	8	116.89	9	92.38	11	82.91	11	144.44	9	116.29
3 years	13	131.36	15	105.57	15	95.89	10	176.56	9	142.97
4 years	7	145.51	7	108.53	5	102.06	5	194.20	6	157.97
5 years	7	152.60	7	114.09	7	108.40	8	195.94	7	161.90
6 years	3	173.67	2	133.33	3	112.67	2	240.50	2	190.00
7 years	1	184.00	1	144.00	1	130.50	1	262.00	1	199.00
8 years	2	172.50	2	141.00	2	128.10	-	-	-	-
9 years	1	208.00	1	164.00	1	149.00	-	-	-	-
Later medieval England										
0 years	6	88.43	3	72.63	3	65.10	4	107.90	5	88.88
1 year	9	116.54	7	88.24	5	84.86	11	152.62	10	121.40
2 years	9	132.99	3	102.47	3	101.07	7	174.66	5	139.28
3 years	7	137.07	4	112.75	2	102.20	5	178.40	3	132.27
4 years	8	152.33	5	128.52	6	117.07	4	208.78	8	170.41
5 years	11	164.86	7	128.36	6	118.17	9	218.22	8	172.88
6 years	7	181.71	7	142.86	6	129.17	10	247.10	7	192.43
7 years	6	186.17	6	153.08	8	136.25	8	254.25	7	206.43
8 years	3	184.67	3	177.33	2	142.00	2	289.50	1	234.00
9 years	7	212.71	6	169.83	5	160.60	6	294.17	8	227.88

Table 3. *Calculated mean z-score values and standard deviations for children at Tõnismägi, and the English sample, by age group.*

Age group	Humerus			Ulna			Radius			Femur			Tibia		
	n	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**
Tõnismägi															
0–1 year	32	-0.64	0.60	16	-0.97	0.85	20	-0.96	0.63	20	-1.03	0.74	10	-0.73	0.33
2–3 years	15	-1.58	1.48	10	-2.28	1.37	12	-1.69	1.43	6	-2.75	2.97	5	-3.22	1.27
4 –9 years	14	-4.46	3.29	11	-4.01	2.06	13	-4.89	2.90	12	-6.26	2.97	9	-6.87	0.95
Industrial period England															
0–1 year	29	-1.40	1.26	19	-1.88	1.38	22	-1.75	1.34	22	-1.28	1.79	10	-0.46	1.06
2–3 years	21	-3.03	2.20	24	-4.28	2.51	26	-3.85	2.37	21	-3.46	2.07	18	-3.58	1.99
4–9 years	21	-5.02	3.09	21	-8.07	3.41	19	-6.95	2.95	16	-5.81	3.99	16	-5.68	2.78
Later medieval England															
0–1 year	15	0.74	0.90	10	-0.75	2.89	8	0.17	0.94	15	0.67	1.07	15	0.50	1.21
2–3 years	16	-0.76	2.11	7	-2.19	2.48	5	-0.45	2.31	12	-1.34	2.04	8	-2.24	2.59
4–9 years	42	-2.95	4.00	34	-3.35	3.98	33	-3.51	4.29	41	-3.71	3.37	39	-4.88	4.03

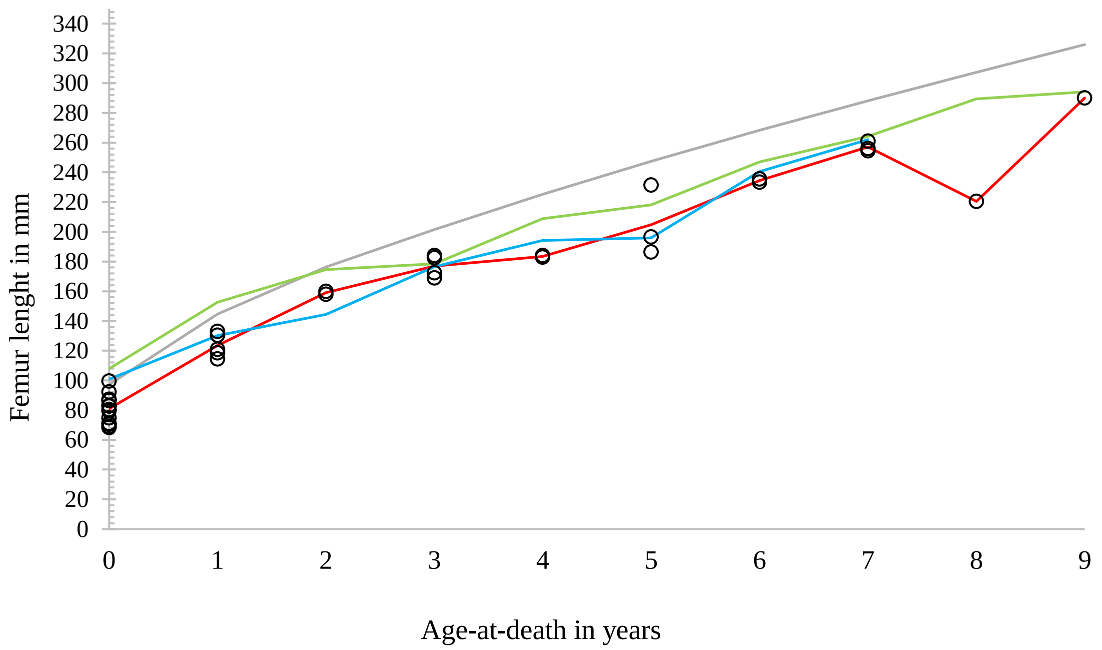
n- number of individuals (bones present), mean – mean of z-score values, SD- standard deviation of z-score values.

There was a statistically significant difference in z-scores between the three samples for all bones in the first age group ($p<0.023$), whereas for the remaining age categories the differences are significant for all but the tibia (Table 4). Post-hoc pairwise analysis showed that the growth of the children from Tõnismägi and those from industrial England were similar (except for the radius in the 2–3-year group and ulna in the 4–9-year group). When the Tõnismägi children were compared with those from later medieval England, the results are inconsistent. Most bones show significant differences in their diaphyseal lengths (excluding the ulna) for the youngest age group, but in the older age groups the majority of comparisons are statistically similar (excluding the femur for the 4–9-year group). The results show that for the 0–1-year olds, Tõnismägi children had a similar growth pattern to their peers from industrial England, but different from children living in medieval England, whose z-scores were relatively higher (Table 2).

Table 4. *Kruskal-Wallis H tests and post-hoc pairwise comparisons for differences in long bone diaphyseal lengths between Tõnismägi and English non-adults. Statistically different values marked in bold.*

0–1-year olds	**Kruskal-Wallis H**		**Post-hoc comparison (p-values)**		
	Test statistic	**p value**	**Tõnismägi vs Industrial**	**Tõnismägi vs Medieval**	**Industrial vs Medieval**
Humerus	32.008	**<0.001**	0.067	**0.000**	**0.000**
Ulna	8.7840	**0.012**	0.196	0.665	**0.013**
Radius	15.328	**<0.001**	0.166	**0.048**	**0.000**
Femur	17.989	**<0.001**	1.000	**0.000**	**0.001**
Tibia	7.5470	**0.023**	1.000	**0.034**	0.142
2–3-year olds	**Kruskal-Wallis H**		**Post-hoc comparison (p-values)**		
	Test statistic	**p value**	**Tõnismägi vs Industrial**	**Tõnismägi vs Medieval**	**Industrial vs Medieval**
Humerus	10.324	**0.006**	0.146	0.894	**0.005**
Ulna	5.9960	**0.050**	0.111	1.000	0.227
Radius	11.245	**0.004**	**0.050**	0.914	**0.014**
Femur	7.5220	**0.023**	1.000	0.456	**0.019**
Tibia	1.6780	0.432	1.000	1.000	0.587
4–9-year olds	**Kruskal-Wallis H**		**Post-hoc comparison (p-values)**		
	Test statistic	**p value**	**Tõnismägi vs Industrial**	**Tõnismägi vs Medieval**	**Industrial vs Medieval**
Humerus	8.080	**0.018**	1.000	0.204	**0.026**
Ulna	17.893	**<0.001**	**0.011**	1.000	**0.000**
Radius	8.7440	**0.012**	0.205	1.000	**0.010**
Femur	7.2890	**0.026**	0.841	**0.031**	0.434
Tibia	3.9500	0.139	0.381	0.142	1.000

These growth differences are further illustrated by skeletal growth profiles for femur and tibia (Figure 2). While individuals from all samples were generally small in comparison to their healthy modern peers, later medieval English children were more advanced in growth compared to the other two groups. Tõnismägi and the English post-medieval non-adults, on the other hand, show similar growth patterns, particularly for the femur, but between the ages of 3 and 7 years, the Tõnismägi children lagged behind those from post-medieval England.



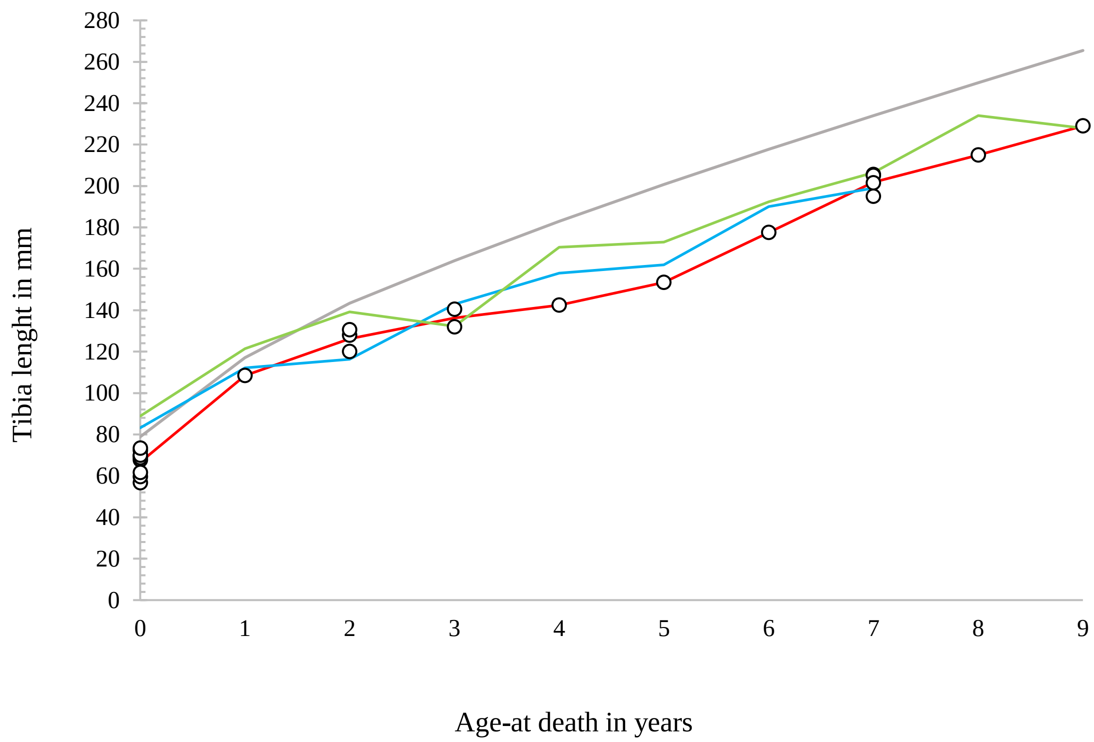


Figure 2. *Growth profiles for the tibia (above) and femur (below). Light grey line: mean long bone length values of modern healthy children (Maresh, 1970); red line: corresponding mean values of Tõnismägi non-adults; blue line: corresponding mean values of industrial period English children; green line: corresponding mean values of later medieval period English non-adults; Circles: long bone values of individual Tõnismägi children.*

Out of the 25 individuals who displayed faltered growth, 24 were preserved well enough to be assessed for skeletal pathology related to metabolic and respiratory diseases, with 60% (n=15) displaying evidence of a chronic condition. A chi-square test performed on all 69 individuals who could be assessed for growth faltering and pathology indicated no statistically significant association between the two variables ($X^2$1d.f., n=69) = 0.310, p = 0.578). However, there was a statistically significant correlation between individuals with a respiratory disease and growth faltering ($X^2$1d.f., n=53) = 15.682, p = <0.001). The z-score values of children with chronic conditions all fell below or at 3 SD of the modern mean, and were consistently lower than those with no obvious skeletal pathology from the age of 6 years onwards (Figure 3). Figure 3 shows three outliers. Two of these individuals had pathological changes; an 8-year old with a very high z-score (-14.29) showing lesions indicative of chronic TB and a 5-year old (z-score: -8.43) with unspecified respiratory infection. Another 5-year old (z-score: -8.77) had subperiosteal new bone formation on the tibia, but no indication of any condition that may have caused such delayed growth. The data and measurements regarding these outliers were double checked by the first author to eliminate any possible ageing or measurement errors.

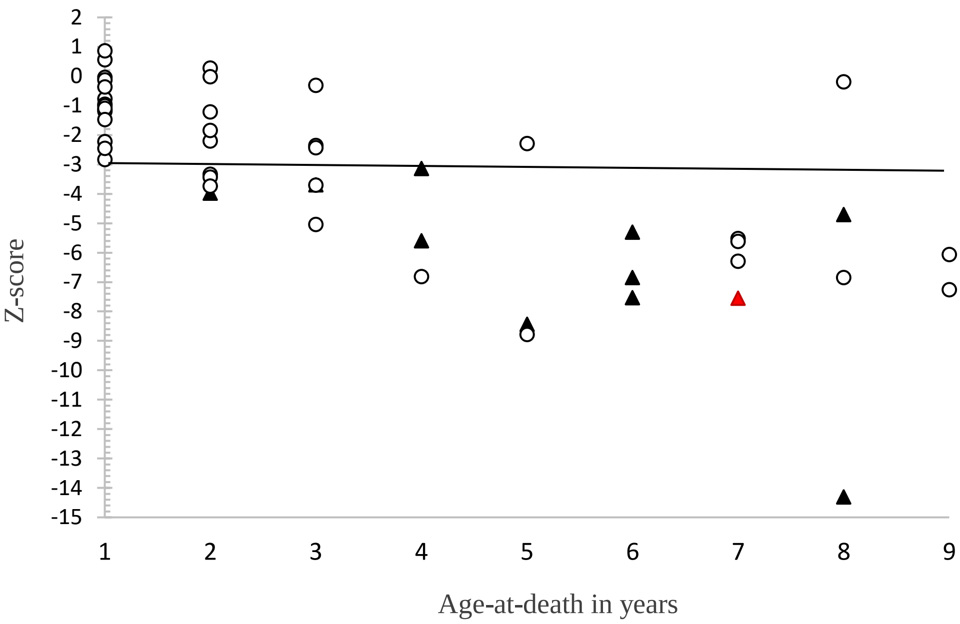


Figure 3. *Individual z-score values from Tõnismägi sample. Circles denote Tõnismägi non-adults without the aforementioned pathologies, black triangles mark Tõnismägi individuals with at least one recorded pathology. Z-score values were derived from the length of tibia and femur or if these were absent calculated*

from all available arm bones. Individuals that fall below -3 SD value (marked with a black line) display severe growth faltering in comparison to modern healthy children. The red triangle indicates the child with lesions compatible with possible TB (see Figure 6).

A total of 102 non-adults were preserved well enough to be assessed for vitamin C deficiency, with a total of 45.1% (n=46) displaying lesions suggestive of scurvy (Table 5; Figures 4 and 5). Signs of scurvy were found in 17.6% (n=18) of the children, and possible scurvy in a further 27.5% (n=28). The highest prevalence of scurvy (including possible cases) was observed among the 0.0–1.0-year olds (70%, n=21). No signs of the disease were identified after 10.5–17.0 years.

Table 5. *Prevalence of scurvy and possible scurvy, vitamin D deficiency, metabolic disease, possible TB and unidentified respiratory infection among the Tõnismägi children.*

Age in years	**Scurvy**		**Possible scurvy**		**Vitamin D deficiency**		**Metabolic disease**		**Possible TB**		**Respiratory infection**	
	Obs.	**Aff. n/%**	**Obs.**	**Aff. n/%**	**Obs.**	**Aff. n/%**	**Obs.**	**Aff. n/%**	**Obs.**	**Aff. n/%**	**Obs.**	**Aff. n/%**
Perinate	8	0	8	1 / 12.5	9	0	17	0	0	0	0	0
0.0–1.0	30	12 / 40.0	30	9 / 30.0	23	0	38	2 / 5.3	19	0	19	0
1.1–2.5	31	4 / 12.9	31	11 / 35.5	20	1 / 5.0	38	2 / 5.3	19	0	19	2 / 10.5
2.6–6.5	17	2 / 11.8	17	5 / 29.4	16	0	23	0	16	0	16	3 / 18.8
6.6–10.5	9	0	9	2 / 22.2	7	0	15	0	7	3 / 42.9	7	0
10.6–14.5	3	0	3	0	4	0	8	0	1	1 / 100	1	0
14.6–17.0	2	0	2	0	3	0	6	0	2	1 / 50	2	0
Non-adult	2	0	2	0	6	0	46	0	1	0	1	1 / 100
Total	**102**	**18 / 18.6**	**102**	**28 / 27.5**	**87**	**1 / 1.2**	**191**	**4 / 2.1**	**68**	**5 /7.4**	**68**	**6/ 8.8**

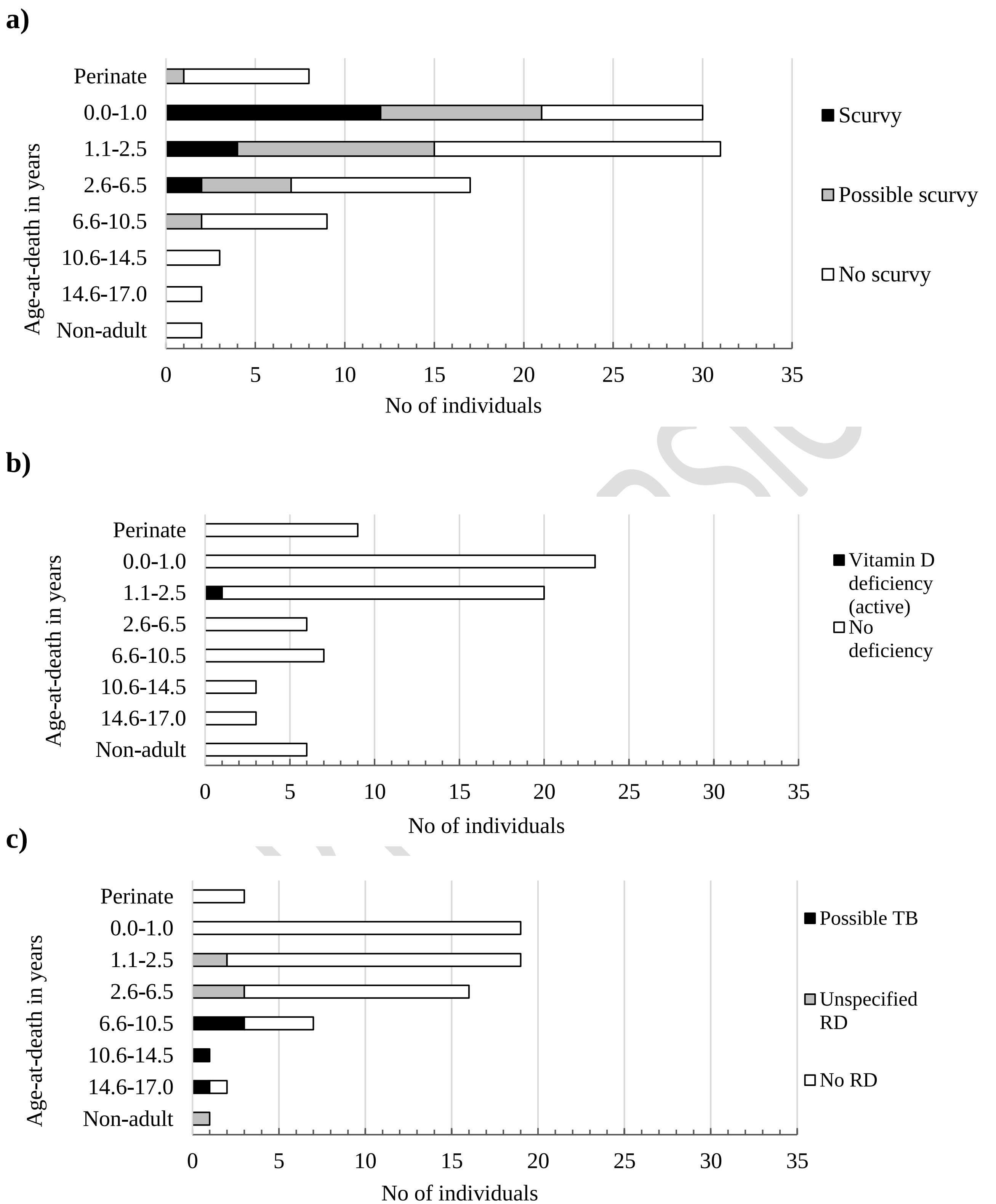


Figure 4. *a) Scurvy and possible scurvy by age groups; b) vitamin D deficiency by age groups; c) tuberculosis (TB) and unidentified respiratory disease (RD) by age groups.*

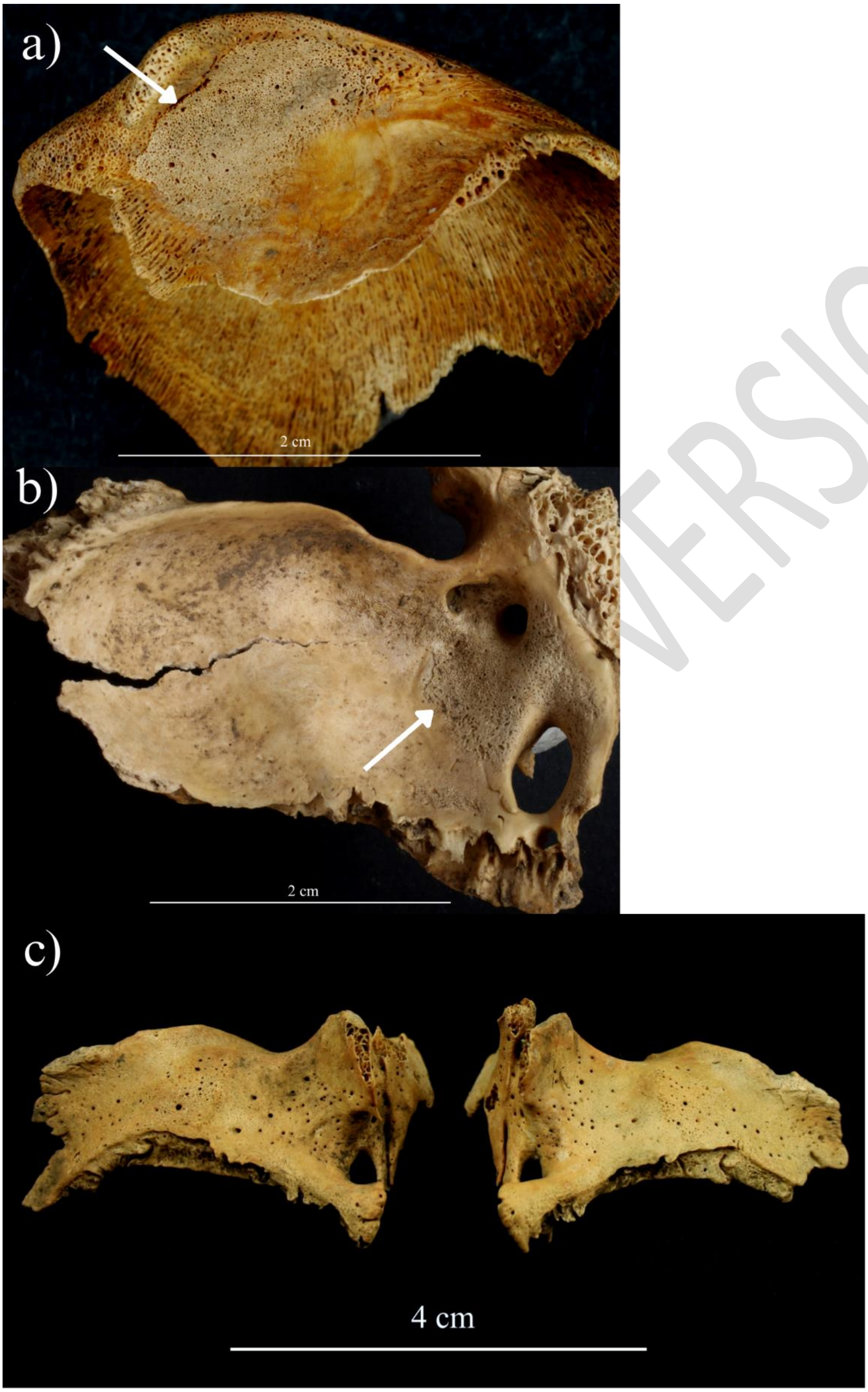


Figure 5. *Lesions indicative of vitamin C deficiency. a) PNBF on the orbital roofs of a perinate (marked with a white arrow; burial 103); b) PNBF at the foramen rotundum of the sphenoid in a 2.6–2.5-year-old (marked*

with a white arrow; burial 222); c) bilateral abnormal porosity on the ectocranial surface of the greater wings of sphenoid in an infant (burial 43a).

Eighty-seven individuals could be evaluated for signs of possible vitamin D deficiency. One child with a mean age of at least 2.1 years (n=1/18 in the age group; 5.6%) displayed signs compatible with active form of the disease (Table 5). The observed lesions included bowing of the humeri, porosity of the growth plates of all the arm bones (the lower extremities were absent), porosity and fraying of the epiphyses and costochondral ends of the ribs together with rib fractures, new bone formation on the ectocranial surface and possible fracture of the left ulna. Four additional non-adults aged between 1.1–6.5 years displayed only bilateral deformation of their lower limb bones, which could suggest residual rickets, however these cases were excluded as no other macroscopic nor radiographic signs indicative of the disease were found and therefore differential diagnosis could not be ruled out. Four individuals aged between 0.0–2.5 years displayed lesions (e.g. general osteopenia, porosity and fraying of the costochondral ends of the ribs) caused by either one or both of the diseases and were categorised as suffering from a general metabolic disorder.

Sixty-eight non-adults were preserved well enough to be analysed for TB and respiratory diseases in general. A total of 7.4% (n=5) displayed lesions indicative of TB (e.g. lytic rib lesions and possible Pott's disease) (Figure 6). Three individuals were aged between 6.6–10.5 years, one was 10.6–14.5 years old and another was 14.6–17.0 years old. Additionally, 8.8% (n=6) of the non-adults displayed new bone formation on the visceral surface of the ribs without any other lesions, indicative of a respiratory disease. These children were aged between 1.1-6.5 years.

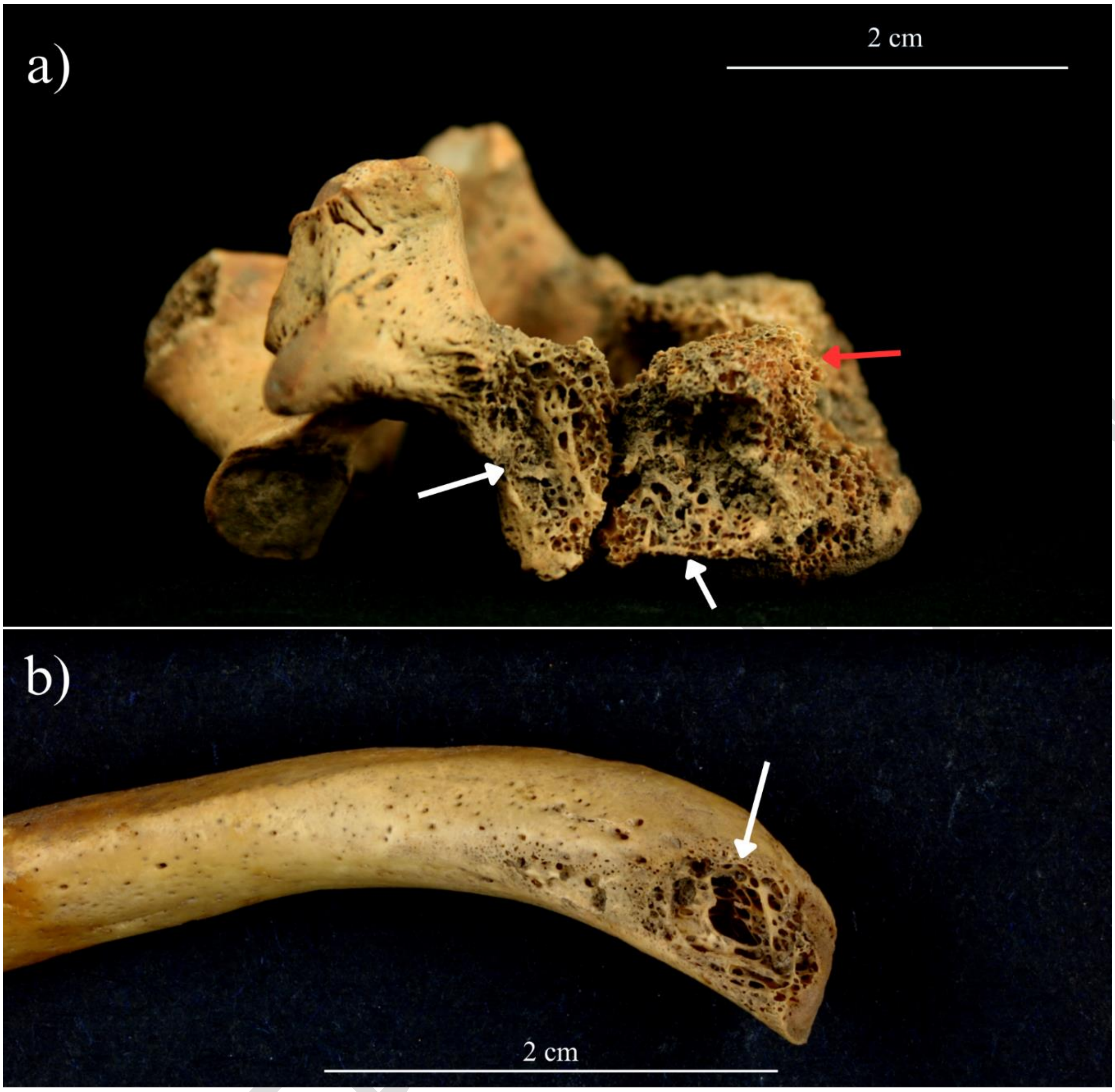


Figure 6. *Lesions indicative of tuberculosis (marked with white arrows) in a 6.6–10.5-year old (burial 214). a) Probable psoas abscess on the vertebral body of L1 (red arrow indicates post-mortem damage);b) Lytic lesion on the head of a left rib.*

4 DISCUSSION

4.1 Child mortality and growth

In the Tõnismägi sample, at least 60% of the children died before the age of seven years. This correlates with historical data from the 18th century where at least half of the registered deaths in Tallinn were in children under the age of 13 years. Infant mortality was the highest in lower social status families, with over 65% of the children reportedly dying within the first month of life (Pullat, 1992). The actual death rates of babies born in the region was likely even greater because unbaptized children (stillbirths, infanticide victims) were not commonly buried on consecrated ground and so would not be recorded (Põltsam-Jürjo 2017; 2018b).

Although Hodson & Gowland (2019) have demonstrated severe growth disruption among infants from post-medieval England, perinates were not included in the current growth study due to the absence of dental crowns. However, a lack of growth faltering in the infants a good maternal environment, given the poor socioeconomic status of their potential mothers it seems more likely that the Tõnismägi babies may have died before growth faltering became evident (DCRBMD, 1724–1758; Wood et al., 1992). This is further supported by Pullat (1992), who suggested that among the lower social class, over 12% of the children were stillborn or born prematurely. Neonatal deaths were high because mothers often worked strenuous jobs throughout the pregnancy, and had less medical help during labour than upper class women (Pullat, 1992).

There is ample evidence from bioarchaeological studies that factors linked with poverty, such as poor nutrition, infectious disease, harsh working conditions and overcrowded, unsanitary, and polluted environmental conditions heightened morbidity, mortality, and growth impairment among children (Buckberry & Crane-Kramer, 2022; DeWitte et al., 2016; Hodson & Gowland, 2019; Newman & Gowland, 2017). The growth of children buried at Tõnismägi lagged behind their modern and later medieval peers, particularly between 6-9 years, and was more comparable to children from industrialised London. Tallinn in the 16–18th century had not reached the same level of industrialisation as London, whose poor inhabitants experienced severe air pollution, overcrowding and dreadful factory working conditions (Vinnal, 2019). However, this life stage (around six years) broadly coincides with the historical accounts of when children began to work, helping to run the household, possibly starting school and taking on jobs like herding cattle (Kõiv, 2019; Põltsam-Jürjo, 2017). Older girls often worked as maids for the upper-class families, whereas boys would have become apprentices to craftsmen which meant leaving their home and being exposed to physically strenuous jobs with long work hours (Kröönström, 2018; Põltsam-Jürjo, 2017; 2019). It has been suggested that together with such life changes, the diet of children became similar to that of adults, with increased protein and nutritional value (Morrone et al., 2023; Põltsam-Jürjo, 2017). While an improved nutrition would have benefitted these children, the strenuous work and possible change in environment still left its mark on their health, reflected by the continuous growth faltering (Steckel, 2012). Several of the Tõnismägi non-adults would have been inmates of the poorhouse, suggesting serious health problems, or that they were orphans or beggars (DCRBMD, 1724–1758), adding to the likelihood of this growth impairment.

Future research on the growth of the adolescents from Northern Estonia (10–25 years) will reveal whether they suffered similar growth disruption, whether this was the same for males and females, and how conditions in Tallinn affected their reproductive development (Lewis, 2022).

4.2 Growth faltering and tuberculosis

There was a statistically significant positive correlation between children suffering from growth faltering and respiratory infections, including TB. This is in accordance with a study by Gooderham et al. (2020) who also identified this link in medieval Portugal. Three of the five individuals with signs of TB had z-score values ranging from -4.70 to -14.29 indicating a severe growth disruption; the two other affected individuals could not be assessed for growth. Four additional children aged between 1.1 and 6.5 years had visceral rib lesions and faltered growth. As no cases of TB were detected among non-adults younger than 6.5 years, it is possible that some of the older children suffered from latent TB that reactivated as their immunity response changed, or nutritional health declined (Roberts & Manchester, 2010). Alternatively, they may have been newly exposed to the infection from their parents (Walls and Shingadia, 2004), in their workplace or in the poorhouse. Although contracting TB from animals is not as common, many children would have been in close contact with them, or the infection could have originated from consuming contaminated milk (Roberts & Buikstra, 2019). Evidence for the disease in the children however, provides the first evidence that an ongoing transmission of tuberculosis was present in the wider population of Tallinn (Lewis, 2018: 156).

4.3 Childhood metabolic diseases

Vitamin C deficiency generally reflects an insufficient diet or food preparation practices, but particularly high rates of it can arise due to catastrophic events such as famines (Brickley et al., 2020; Geber & Murphy, 2012). Although the available archaeological and historical evidence for Tõnismägi does not fully support this, it is possible that the diet of these children was indirectly affected by famines caused by crop failures and military conflicts which impacted general food availability and dietary variability throughout the Early Modern Period (Malve, 2018; Kröönström & Põltsam-Jürjo, 2019a). The prevalence of scurvy in the Tõnismägi sample may also be related to the staple food of the urban poor – rye bread, as cereals do not contain any vitamin C (USDA, 2018). Although vegetables and fruit were accessible, their nutritional value is depleted over time (Lee & Kader, 2000), and a lack of fresh fruit and vegetables has been linked to outbreaks of scurvy at the end of each winter (Cheung et al., 2003; Maat, 2004).

The distribution of scurvy in only the youngest children suggests that the main cause of scurvy was not seasonal. As in cases of seasonal outbreaks one would also expect to find evidence of the disease in the older children (Maat, 2004). The prevalence of vitamin C deficiency was highest among infants, with 40% (n=12/30) showing clear signs of the condition. With each following age category, the prevalence of lesions decreased, although skeletal lesions arising from haemorrhage of scurvy are generally most marked in younger individuals and can be more subtle for adolescents (Brickley et al., 2020). Differentiating such pathological changes from those representing normal healthy growth in perinates and young infants remains difficult (Lewis, 2017: 132), and as the possible cases of the disease are not included here, the true prevalence of scurvy at Tallinn may have been higher.

Signs of scurvy in infants and young children usually suggest maternal deficits in vitamin C as the result of a poor maternal diet, limited breastfeeding and a poor weaning diet (Snoddy et al., 2017; Mays and Brickley, 2022). Nutritional deficiencies can cause delay in both skeletal and dental development meaning some of these children may have been slightly older than has been estimated (Brickley et al., 2020: 49). Many widowed, sick, or impoverished women, possibly including a number of mothers of the Tõnismägi children stayed at the Dome Church hospital (DCRBMD, 1724–1758). Factors arising from poverty might have made these women susceptible to developing nutritional deficiencies, which could have been passed on to their offspring via breastmilk. Historians suggest that a substantial number of suburban women were prostitutes, or servants for the upper class who would have been fired if they fell pregnant when unwed (Põltsam-Jürjo, 2009). These factors would have increased the risk of poverty. Historical accounts from the beginning of 20th century across Estonia suggest that breastfeeding was generally practised for about a year and was highly dependent on the socioeconomic status of the mother. Infants of poorer mothers often received breastmilk only for a very limited time as their mothers needed to return to work, and supplementary foods were first provided 2–3 months after birth. For others, breastfeeding could last for up to three years, even in poorer households (Gustavson, 1969; Rammul & Kask, 1938; Rammul, 1931). Recent stable isotope analysis of children from Southern Estonia indicates that breastfeeding was practised for one to two years, and supplementary foods were given before one year of age (Morrone et al., 2023). Other authors have linked the presence of scurvy with weaning practices, especially with the use of heated cereal-based foods such as gruel or panada (e.g. Bourbou, 2014; Mays, 2014). Similar foods were likely given to Tõnismägi infants, as the general population was highly reliant on cereal, with historical records also mentioning foods such as cow's milk diluted with water, light soup or other soft foods (Gustavson, 1969; Pullat, 1992; Rammul & Kask, 1938; Rammul, 1931).

Although recently there has been some debate about rickets reflecting dietary calcium deficiency, the disease is generally viewed as a reflection of severe vitamin D deficiency mainly arising from lack of sunlight (Brickley et al., 2020; Vlok et al., 2022). In contrast to high rates of scurvy, severe vitamin D deficiency was rare, affecting one child (1.1–2.5 years), although there were several more cases of unspecified metabolic disease in the sample that may have been mild cases (Brickley et al., 2020; Ives, 2018). Historical sources of the time suggest that although 18th century Tallinn children did suffer from rickets, it was rarely severe enough to cause notable deformities (Bluhm, 1790). The lack of evidence for this condition in the low status Tõnismägi children is notable, especially when compared to the rates reported from other post-medieval populations across Europe (1% compared to 12% and 20%; Newman & Gowland, 2017; Newman et al., 2019; Veselka, 2013). This suggests the children in Tallinn had better access to sunlight than their counterparts living in larger cities. The presence of gardens in the suburbs suggests access to green spaces, and historical accounts suggest toddlers were often left to their own devices and described as wearing insufficient clothing (Põltsam-Jürjo, 2017; Rammul, 1938). Consequently, they might have spent more time outside, with their skin exposed to sunlight.

It is possible that the single child suffering from rickets at this site developed the condition for other reasons. For example, the child might have been already suffering from another illness and was kept indoors, consequently developing rickets (Ortner & Mays, 1998; Pētersone -Gordina, 2013). The child may have had renal rickets and hyperparathyroidism (Levene, 1991), but the presence of rib fractures and a possible fracture of the ulna means that neglect and physical abuse of this child cannot be ruled out. Future analyses of other Estonian urban and rural cemetery samples will help to shed more light on the prevalence of vitamin D deficiency among the non-adult population and the possible factors affecting it.

4.4 Limitations of the study

The small sample size and the general scarcity of individuals older than nine years of age made it difficult to study the health of adolescents. A more in depth analysis of perinatal growth in relation to maternal health was also limited by the lack of surviving dentition for these young individuals. Although the lack of suitable comparative data from the region hindered the interpretation of results, investigations concerning the adult individuals from Tõnismägi and other contemporaneous non-adult skeletal collections are underway, potentially offering evidence about health differences, such as prevalence of TB between life stages and populations (e.g. rural and urban) and help to draw parallels between female and infant health.

5 CONCLUSIONS

Analysis of 191 non-adult skeletons from the Tõnismägi sample shed a light on the health hazards and living conditions endured by suburban Tallinn children who have previously stayed virtually invisible in both historical and archaeological records. Poor socioeconomic status combined with unsanitary and possibly overcrowded living conditions of the suburbs evidently had a detrimental effect on the health and growth of these children. Four to nine-year-old children suffered from growth faltering which in its severity, was comparable to that of children living in industrialised London.

Furthermore, there was a statistically significant correlation between growth disruption and respiratory infections. The high prevalence of scurvy was likely caused by consumption of weaning foods devoid of vitamin C, possibly reflecting a problem arising from cultural practices and impoverished status of both the children and their mothers. The observed growth deficit together with a high infant mortality and rates of scurvy and possible cases of TB provide evidence for unfavourable dietary and living conditions of the poor suburban inhabitants. Conversely, the low rate of vitamin D deficiency suggests that children living in Tallinn were not deprived of sun exposure like their counterparts in other parts of Europe during that period.

ACKNOWLEDGEMENTS

The authors thank Janika Viljat and Lisette Reinvars for photographic material, and the latter also for the photo editing. Thanks are due to historian and archivist Kalmer Mäeorg for providing information about the archival documents referenced in this paper.

CONFLICT OF INTEREST STATEMENT

The authors report no conflict of interest.

DATA AVAILABILITY STATEMENT

Data used in this paper are available upon request to the first author.

ORCID

Linda Vilumets https://orcid.org/0000-0002-2376-7736

Ülle Aguraiuja-Lätti https://orcid.org/0000-0002-5464-4712

Mary Lewis: https://orcid.org/0000-0001-6224-0278

REFERENCES

Aguraiuja-Lätti, Ü., & Lõugas, L. (2019). Stable isotope evidence for medieval diet in urban and rural northern Estonia. *Journal of Archaeological Science: Reports*, 26. https://doi.org/10.1016/j.jasrep.2019.101901

Allmäe, R. (1997). The stature reconstruction of children on the basis of paleoosteological materials. *Papers on Anthropology*, 7, 44–55.

Allmäe, R. (1998). Tääksi 14.–18. sajandi populatsiooni demograafiline analüüs ja kehapikkuse rekonstrueerimine. In V. Lang (Ed.), *Nature, man and technology: Interdisciplinary studies in archaeology. Muinasaja Teadus, 5.* (pp. 163–187). Tallinn: Eesti TA Ajaloo Instituut.

AlQahtani, S. J., Hector, M. P., & Liversidge, H. M. (2010). Brief communication: The London atlas of human tooth development and eruption. *American Journal of Physical Anthropology*, *142*(3), 481–490.

Bernotas, R., Randoja, K., & Malve, M. (2017). Aruanne arheoloogilistest eeluuringutest Tallinnas Tõnismägi 11a/Pärnu mnt 44 (asulakohtade reg nr 2593 ja 2596 kaitsevööndis). Tartu.

Bluhm, H. (1790). *Versuch einer Beschreibung der hauptsächlisten in Reval herschenden Krankheiten*. Marburg.

Bogin, B. (2021). *Patterns of Human Growth* (3rd ed.). Cambridge University Press.

Bourbou, C. 2014. Evidence of childhood scurvy in a Middle Byzantine Greek population from Crete, Greece (11th–12th centuries AD). *International Journal of Paleopathology*, 5, 86–94.

Brickley, M., Ives, R., & Mays, S. (2020). *The Bioarchaeology of Metabolic Bone Disease* (2nd ed.). New York: Academic Press.

Buckberry, J., & Crane-Kramer, G. (2022). The dark satanic mills: Evaluating patterns of health in England during the industrial revolution. *International Journal of Paleopathology*, 39, 93–108.

Cardoso, H. F., & Garcia, S. (2009). The Not-so-Dark Ages: Ecology for human growth in medieval and early Twentieth Century Portugal as inferred from skeletal growth profiles. *American Journal of Physical Anthropology*, *138*(2), 136-147.

Cardoso, H. F. V., Spake, L., Wasterlain, S. N., & Ferreira, M. T. (2019). The impact of social experiences of physical and structural violence on the growth of African enslaved children recovered from Lagos, Portugal (15th–17th centuries). *American Journal of Physical Anthropology*, 168(1), 209–221.

Cheung, E., Mutahar, R., Assefa, F., Ververs, M. T., Nasiri, S. M., Borrel, A., & Salama, P. (2003). An epidemic of scurvy in Afghanistan: assessment and response. *Food and Nutrition Bulletin*, 24(3), 247–255.

Crooks, D. L. (1999). Child growth and nutritional status in a high-poverty community in eastern Kentucky. *American Journal of Physical Anthropology*, 109(1), 129–142.

Cunningham, C., Scheuer, L., & Black, S. (2016). Developmental juvenile osteology. (A. Christie, Illus.). London: Academic Press.

Dawes, J. D., & Magilton, J. R. (1980). *The Cemetery of St. Helen-on-the-Walls, Aldwark.* (Vol. 12/1). London: Council for British Archaeology.

DeWitte, S. N., Hughes-Morey, G., Bekvalac, J., & Karsten, J. (2016). Wealth, health and frailty in industrial-era London. *Annals of Human Biology*, *43*(3), 241–254.

Dunn, O. J. (1964). Multiple comparisons using rank sums. *Technometrics*, *6*(3), 241–252.

Geber, J., & Murphy, E. (2012). Scurvy in the Great Irish Famine: Evidence of vitamin C deficiency from a mid-19th century skeletal population. *American Journal of Physical Anthropology*, *148*(4), 512–524.

Gooderham, E., Marinho, L., Spake, L., Fisk, S., Prates, C., Sousa, S., Oliveira, C., Santos, A. L., & Cardoso, H. F. (2020). Severe skeletal lesions, osteopenia and growth deficit in a child with pulmonary tuberculosis (mid-20th century, Portugal). *International Journal of Paleopathology*, *30*, 47–56.

Gowland, R. L., Caffell, A. C., Newman, S., Levene, A., & Holst, M. (2018). Broken childhoods: rural and urban non-adult health during the Industrial Revolution in Northern England (eighteenth-nineteenth centuries). *Bioarchaeology International*, 2(1), 44–62.

Gustavson, H. (1969). *Meditsiinist vanas Tallinnas.* Kirjastus Valgus, Tallinn.

Hodson, C. M., & Gowland, R. (2019). Like Mother, Like Child: Investigating Perinatal and Maternal Health Stress in Post-medieval London. In Gowland R. & Halcrow S (Eds), *The Mother-Infant Nexus in Anthropology: Small Beginnings, Significant Outcomes*. Springer, Cham. 39–64.

Ives, R. (2018). Rare paleopathological insights into vitamin D deficiency rickets, co-occurring illnesses, and documented cause of death in mid 19th century London, UK. *International Journal of Paleopathology*, 23, 76–87.

Ives, R., & Humphrey, L. (2020). Exploring patterns of appositional growth amongst urban children. In T. K. Betsinger & S. N. DeWitte (Eds.), *The bioarchaeology of urbanization: The biological, demographic, and social consequences of living in cities* (pp. 317–339). Springer.

Jankauskas, R. (1992). Osteometry of the 14th–17th cc children's skeletons in Lithuanian paleoosteological materials. *Papers on Anthropology V. Acta et commentationes universitatis Tartuensis*, *951*, 36–46.

Kirchenbuch: Verzeichnis der Copulierten. Verzeichnis der Getauften. Verzeichnis der Verstorbenen. 1724–1758. TLA.237.1.23 Tallinna Linnaarhiiv, Tallinn. = Dome Church Registry of Births, Marriages and Deaths; DCRBMD)

Kröönström, T. (2018). Orbudekool Toompea eeslinnas kui pietistlike haridusuuenduste ilming. In K, Kaju (Comp.), *Uutmoodi ja paremini! Ühiskondlikest muutustest 18. sajandil ja 19. sajandi algul. Rahvusarhiivi toimetised*, 28/33 (pp. 7–43). Rahvusarhiiv, Tartu.

Kröönström, T., & Põltsam-Jürjo, I. (2019a). Näljahädad ja haigused. In T, Kala (Ed.), *Tallinna ajalugu II: 1561–1710* (pp. 272). Tallinna Linnaarhiiv, Tallinn.

Kröönström, T. & Põltsam-Jürjo, I. (2019b). Heakord. In T, Kala (Ed.), *Tallinna ajalugu II: 1561–1710 (pp.* 279–281). Tallinna Linnaarhiiv, Tallinn.

Kröönström, T. & Põltsam-Jürjo, I. (2019c). Kodune olme, toit ja rõivastus. In T, Kala (Ed.), *Tallinna ajalugu III: 1710–1917* (pp. 364–370). Tallinna Linnaarhiiv, Tallinn.

Kõiv, L. (2019). Koolide liigid ja alluvus. In T, Kala (Ed.), *Tallinna ajalugu II: 1561– 1710 (pp.* 227–228). Tallinna Linnaarhiiv, Tallinn.

Küng, E. (2019a). Tallinna eestlased. In T, Kala (Ed.), *Tallinna ajalugu II: 1561–1710* (pp. 70). Tallinna Linnaarhiiv, Tallinn.

Küng, E. (2019b). Elanike arv. In T, Kala (Ed.), *Tallinna ajalugu II: 1561–1710* (pp. 71–72). Tallinna Linnaarhiiv, Tallinn.

Lee, S. K., & Kader, A. A. (2000). Preharvest and postharvest factors influencing vitamin C content of horticultural crops. *Postharvest Biology and Technology*, 20(3), 207–220.

Levene, M. (1991). Metabolic disorders. In M. Levene (Ed.), *Jolly's Diseases of Children* (6th Edition ed., pp. 370-381). London: Blackwell Scientific Publications.

Lewis, M. E. (2002). Impact of industrialization: Comparative study of child health in four sites from medieval and postmedieval England (AD 850–1859). *American Journal of Physical Anthropology*, 119(3), 211–223.

Lewis, M. E. (2007). The bioarchaeology of children: Perspectives from biological and forensic anthropology. Cambridge: Cambridge University Press.

Lewis, M. (2008). The Children. In J. Magilton., F. Lee & A. Boylston (Eds.), *Chichester Excavations 'Lepers Outside the Gate' Excavations at the Cemetery of the Hospital of St James and St Mary Magdalene, Chichester, 1986–87 and 1993.Vol 10* (pp. 174–186). York: Council for British Archaeology Research Report, 158.

Lewis, M. (2017). *Paleopathology of Children: Identification of Pathological Conditions in the Human Skeletal Remains of Non-Adults*. New York: Academic Press.

Lewis, M. E. (2022). Exploring adolescence as a key life history stage in bioarchaeology. *American Journal of Biological Anthropology*, 179(4), 519–534.

Malve, M. (2018). Tallinna Tõnismäe kalmistu eksperdihinnang. Arheoloogiakeskus MTÜ. Tartu.

Malve, M., Viljat, J., Rannamäe, E., Vilumets, L., & Ehrlich, F. (2020). Archaeological fieldwork at Pikk Street and St Michael's churchyard, Rakvere. *Archaeological Fieldwork in Estonia* 2019, 189–212.

Maresh, M. M. (1970). Measurements from roentgenograms. In R.W. Mccannon (Ed.), *Human Growth and Development* (pp. 157–188). Springfield: Charles C Thomas Publisher.

Maat, G. J. R. (2004). Scurvy in adults and youngsters: the Dutch experience. A review of the history and pathology of a disregarded disease. *International Journal of Osteoarchaeology*, 14(2), 77–81.

Mays, S. (2014). The palaeopathology of scurvy in Europe. *International Journal of Paleopathology*, 5, 55–62.

Mays, S., & Brickley, M.B. (2022). Is dietary deficiency of calcium a factor in rickets? Use of current evidence for our understanding of the disease in the past. *International Journal of Paleopathology*, *36*, 36–44.

Moorrees, C. F., Fanning, E. A., & Hunt, E.E. (1963a). Formation and resorption of three deciduous teeth in children. *American Journal of Physical Anthropology*, 21, 205–213.

Moorrees, C. F., Fanning, E. A., & Hunt, E.E. (1963b). Age variation of formation stages for ten permanent teeth. *Journal of Dental Research*, 42, 1490–1502.

Morrone, A., Torv, M., Piombino-Mascali, D., Malve, M., Valk, H., & Oras, E. (2021). Hunger, disease, and subtle lesions: Insights into systemic metabolic disease in fetal and perinatal remains from 13th-to 15th-century Tartu, Estonia. *International Journal of Osteoarchaeology*, 31(4), 534–555.

Morrone, A., Tõrv, M., Piombino-Mascali, D., Saupe, T., Sepp, H., Valk, H., Malve, M., & Oras, E. (2023). Children of the grave: Investigating non-adult feeding practices in medieval and early modern Estonia through stable isotope analysis. *Plos One*, *18*(1). https://doi.org/10.1371/journal.pone.0279546

Mäeorg, K., & Maiste, M. (2019). Rahvastik 18.–19. sajandil. In T, Kala (Ed.), *Tallinna ajalugu III: 1710–1917* (pp. 49–54). Tallinna Linnaarhiiv.

Newman, S. L., & Gowland, R. L. (2017). Dedicated followers of fashion? Bioarchaeological perspectives on socio-economic status, inequality, and health in urban children from the industrial revolution (18th–19th C), England. *International Journal of Osteoarchaeology*, 27(2), 217–229.

Newman, S. L., Gowland, R. L., & Caffell, A. C. (2019). North and south: A comprehensive analysis of non-adult growth and health in the industrial revolution (AD 18th–19th C), England. *American Journal of Physical Anthropology*, *169*(1), 104–121.

Norgan, N. G., Bogin, B., & Cameron, N. (2012). Nutrition and Growth. In N. Cameron & L. Schell (Eds.), *Human Growth and Development* (2nd ed., pp 123–152). New York: Academic Press.

Orro, O. (2019a). Eeslinn. In T, Kala (Ed.), *Tallinna ajalugu III: 1710–1917 (pp.* 213–217). Tallinna Linnaarhiiv, Tallinn.

Orro, O. (2019b). Kommunaalmajandus. In T, Kala (Ed.), *Tallinna ajalugu III: 1710–1917* (pp. 357–360). Tallinna Linnaarhiiv, Tallinn.

Ortner, D. J., & Mays, S. (1998). Dry-bone manifestations of rickets in infancy and early childhood. *International Journal of Osteoarchaeology*, *8*(1), 45–55.

Palli, H. (1996). *Eesti rahvastiku ajalugu aastani 1712*. Tallinn. Eesti Teaduste Akadeemia Kirjastus.

Palli, H. (1997). *Eesti rahvastiku ajalugu 1712–1799*. Tallinn. Eesti Teaduste Akadeemia Kirjastus.

Pullat, R (1992). *Eesti linnarahvastik 18. sajandil*. Olion.

Pullat, R. (2014). Söömine ja joomine tallinnas 18. sajandil. *Vana Tallinn*, 25 (29), 133–199.

Pomeroy, E., Stock, J. T., Stanojevic, S., Miranda, J. J., Cole, T. J., & Wells, J. C. (2012). Trade-offs in relative limb length among Peruvian children: extending the thrifty phenotype hypothesis to limb proportions. *PLoS One*, 7(12). https://doi.org/10.1371/journal.pone.0051795

Põltsam-Jürjo, I. 2009. Kõlvatud naised Tallinna eeslinnas anno 1660 ja 1666. *TUNA. Ajalookultuuri ajakiri*, 1, 72–87.

Põltsam-Jürjo, I. 2012. "Hääleib", "saajaleib", "ißeleib" – Eesti leivakultuurist 13.–16. sajandil. *TUNA. Ajalookultuuri ajakiri*, 4, 14–27.

Põltsam-Jürjo, I. (2017). Lastest ja lapsepõlvest 13.–16. sajandi Eestis. *Vana Tallinn*, 28(32), 115–147.

Põltsam-Jürjo, I. (2018a). Kala tähtsusest kaubanduses, majanduses ja toidumenüüs 13.–16. sajandi Eestis. *Acta Historica Tallinnensia*, 24, 3–23.

Põltsam-Jürjo, I. (2018b). "… sest ämmaemandad pole linna heaks vähem vajalikud kui kaplan …" Ämmaemandatest Eestis keskajal ja varauusaja algul. *TUNA. Ajalookultuuri ajakiri* 4, 19–32.

Põltsam-Jürjo, I. (2019). "Suured" ja "väikesed" käsitöötsunftid. Käsitööliste diferentseerumine. In T, Kala (Ed.), *Tallinna ajalugu III: 1710–1917* (pp. 157–160). Tallinna Linnaarhiiv, Tallinn.

Rammul, A., & Kask, M. (1938). *Tartumaa tervishoiuline kirjeldus*. A, Rammul (Ed.) E.V. Tervishoiuvalitsuse ja Tartu Ülikooli Tervishoiu Instituudi väljaanne. Tartu.

Rammul, A. (1931). *Virumaa tervishoiuline kirjeldus.* E.V. Tervishoiuvalitsuse ja Tartu Ülikooli Tervishoiu Instituudi väljaanne. Tartu.

Roberts, C. A., & Buikstra, J. E. (2003). *The Bioarchaeology of Tuberculosis: A global perspective on a re-emerging disease.* Gainesville: University Press of Florida.

Roberts, C., & Manchester, K. (2010). The Archaeology of Disease (3rd ed.). The History Press.

Roberts, C. A., & Buikstra J. E. (2019). Bacterial Infections. In J. E. Buikstra (Ed.), *Ortner's Identification of Pathological Conditions in Human Skeletal remains* (3rd ed., pp. 321–439). New York: Academic Press,

Rootsmäe, L. 1987. *Nakkushaigused surmapõhjustena Eestis 1711–1850*. Valgus, Tallinn.

Santos, A. L., & Roberts, C. A. (2001). A picture of tuberculosis in young Portuguese people in the early 20th century: A multidisciplinary study of the skeletal and historical evidence. *American Journal of Physical Anthropology*, 115(1), 38–49.

Schaefer, M., Black, S., & Scheuer, L. (2009). *Juvenile Osteology: A Laboratory and Field Manual.* (A. Christie, Illus.). London: Academic Press.

Schell, L. M., & Rousman, E. K. (2022). Environmental effects on growth. In N. Cameron & L. Schell (Eds.), *Human Growth and Development* (3rd ed., pp 261–315). New York: Academic Press.

Scheuer, L., Musgrave, J. H., & Evans, S. P. (1980). The estimation of late fetal and perinatal age from limb bone length by linear and logarithmic regression. *Annals of Human Biology*, 7(3), 257–265.

Seppel, M. (2014a). 1601.–1603. aasta näljahäda Eestimaal: I. Kronoloogia, ikalduse ulatus ja sissetulekute langus. *TUNA. Ajalookultuuri ajakiri*, 2, 33–49.

Seppel, M. (2014b). 1601.–1603. aasta näljahäda Eestimaal II: Asustuse vähenemine, näljaabi ja kannibalism. *TUNA. Ajalookultuuri ajakiri*, 3, 25–43.

Smith, H. B. (1991). Standards of human tooth formation and dental age assessment. In M, Kelley & C. Larsen (Eds.), *Advancements in Dental Anthropology* (pp 143–168). New York: Wiley-Liss.

Snoddy, A. M. E., Halcrow, S. E., Buckley, H. R., Standen, V. G., & Arriaza, B. T., (2017). Scurvy at the agricultural transition in the Atacama desert (ca 3600–3200 BP): nutritional stress at the maternal-foetal interface? *International Journal of Paleopathology*, 18, 108–120.

Snoddy, A. M. E., Buckley, H. R., Elliott, G. E., Standen, V. G., Arriaza, B. T., & Halcrow, S. E. (2018). Macroscopic features of scurvy in human skeletal remains: A literature synthesis and diagnostic guide. *American Journal of Physical Anthropology*, 167(4), 876–895.

Sokolovski, V. & Jaanits, K. (2003). Aruanne arheoloogilistest uuringutest Tõnismäe eeslinna kiriku kalmistul Tallinnas, Tõnismägi 11. Tallinn.

Spake, L., & Cardoso, H. F. (2021). Interpolation of the Maresh diaphyseal length data for use in quantitative analyses of growth. *International Journal of Osteoarchaeology*, 31(2), 232–242.

Steckel, R. (2012). Social and Economic Effects on Growth. Human Growth and Development. In N. Cameron & L. Schell (Eds.), *Human Growth and Development* (2nd ed., pp 225–244). New York: Academic Press.

Šereikienė, I., & Jankauskas, R. (2002) Late medieval Lithuanian children growth (according to palaeoosteological material of 14th–17th cc. Alytus burial ground). *Anthropologie*, *40*(2), 157–163.

Šereikienė, I., & Jankauskas, R. (2004). Lithuanian children's growth patterns in the past-an updated medieval sample. *Papers on Anthropology*, *13*, 226–238.

US Department of Agriculture, Agricultural Research Service (2018). USDA National Nutrient Database for Standard Reference, Release 28. http://www.ars.usda.gov/nea/bhnrc/mafcl

Veselka, B., Hoogland, M. L., & Waters-Rist, A. L. (2015). Rural rickets: Vitamin D deficiency in a post-medieval farming community from The Netherlands. *International Journal of Osteoarchaeology*, 25(5), 665–675.

Vinnal, H. (2019). Tallinn tööstuslinnana Põhjasõja lõpust kuni 1870. aastateni. In T. Kala (Ed.), *Tallinna ajalugu III: 1710–1917* (pp. 163–174). Tallinna Linnaarhiiv, Tallinn,

von Hansen, G. (1885). *Die Kirchen und ehemalige Klöster Revals*. Reval.

Walls, T., & Shingadia, D. (2004). Global epidemiology of paediatric tuberculosis. *Journal of Infection*, *48*(1), 13–22.

Wood, J. W., Milner, G. R., Harpending, H. C., Weiss, K. M., Cohen, M. N., Eisenberg, L. E., Hutchinson, D. L., Jankauskas, R., Cesnys, G., Katzenberg, M. A., Lukacs, J. R., McGrath, J. W., Roth, E. A., Ubelaker, D. H. & Wilkinson, R. G. (1992). The osteological paradox: problems of inferring prehistoric health from skeletal samples [and comments and reply]. *Current Anthropology*, 33, 343–370.

World Health Organisation. (2008). Child Growth Standards. https://www.who.int/tools/child-growth-standards

WORD database (2021a), Museum of London. St Brides Lower. https://www.museumoflondon.org.uk/collections/other-collection-databases-and-libraries/centre-human-bioarchaeology/osteological-database/post-medieval-cemeteries/st-brides-lower-post-medieval

WORD database (2021b), Museum of London. Cross Bones. https://www.museumoflondon.org.uk/collections/other-collection-databases-and-libraries/centre-human-bioarchaeology/osteological-database/post-medieval-cemeteries/cross-bones-post-medieval