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INVESTIGATING THE DIETARY LIFE HISTORIES AND MOBILITY OF CHILDREN BURIED IN ST GERTRUDE CHURCH CEMETERY, RIGA, LATVIA, 15TH–17TH CENTURIES AD**

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Carbon and nitrogen isotope profiles were obtained from incremental dentine analysis of 19 non-adults from a cemetery in Riga, Latvia. The research compared the life histories and diet between people buried in two mass graves and the general cemetery. The $\delta^{13}C$ *profiles of several children from the mass graves were similar but did not resemble the patterns seen in children from the general cemetery, suggesting that they probably represented a different population group. The rise in* $\delta^{15}N$ *values towards the end of the life of four individuals from one mass grave suggests they were victims of an historically documented famine.*

KEYWORDS: DIET, FAMINE, STABLE ISOTOPES, CARBON, NITROGEN, COLLAGEN, MOBILITY

INTRODUCTION

This study is based on 19 non-adult individuals excavated from St Gertrude Church cemetery in Riga, Latvia (Fig. 1). The cemetery dates from the 15th–17th centuries AD and was partly excavated ahead of planned building works on the site between August and October 2006. During the excavation, two mass graves (MG) were discovered in addition to the single discrete burials. The site offered a rare opportunity to study short-term dietary changes from birth to death in children who died during a mass mortality event, and to explore several aspects of life and death in this suburban community by applying high-resolution incremental dentine analysis.

Historical background

The Church of St Gertrude is first mentioned in historical sources in 1413. It was built outside the old centre of Riga, and its main purpose was to provide shelter for travellers. It also became the main church for the suburban Gertrude village, named after the church. Gertrude village was small, and its population mostly comprised farmers, servants and craftsmen and their families. The close proximity of the village to Riga, which was a key trading centre during the post-

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Figure 1 *The location of Latvia, Riga, and the region of Vidzeme within Europe.*

medieval period, provided the population with access to various resources arriving in the city (Dunsdorfs 1962).

The cemetery was mainly used as the final resting place for people living in Gertrude village, but it is also mentioned in historical sources as one of the burial places for plague victims from Riga and its suburbs (Pīrangs 1932, 501). The burial ground went out of use in the late 17th century after the church was destroyed and rebuilt elsewhere.

The MG in the cemetery date from the 17th century, during which several documented mass mortality events affected the region. The outbreak of the Polish–Swedish War (1600–29) coincided with a year of poor harvests in the Vidzeme region in 1601, and any remaining food sources were taken from the local subsistence farmers during the raids of the invading Polish army. This caused hundreds of people to leave their homes and migrate to Riga for help. The resulting famine of the winter of 1601–02 was particularly severe. Sources and chronicles written at the time suggest that the city built a shelter for these immigrants and provided some food but, despite this help, many died upon arrival, as well as others from cold and exhaustion later (Das Buch der Aeltermänner grosser Gilde von 1540–1611, 1844, Nyenstädt, 1837, Napiersky, 1890). Many of the dead are believed to have been buried in St Gertrude's cemetery (Rusovs 1926; Pīrangs 1932; Actiņš *et al.* 2009). In the same year (1602) there was an outbreak of plague in the region, and finally another outbreak in 1623 (Napiersky, 1890). Accordingly, one or both MG could have contained the victims of the two documented plague epidemics and/or the famine.

Incremental dentine analysis and justification for its use in the current study

Incremental dentine analysis is a relatively new strand of isotope analysis for studying diet in archaeological human populations (Fuller *et al.* 2003). It is based on the fact that, unlike bone, primary dentine does not remodel after it is formed (Nanci 2003), thus retaining information about childhood diet and stress episodes throughout an individual's life. Moreover, dentine grows at regular intervals every year (Dean and Scandrett 1995), which allows for relatively precise sampling and the assigning of a chronological age for each increment (Beaumont and Montgomery 2015). In essence, this analysis measures carbon and nitrogen isotope ratios in several consecutive dentinal increments from a single tooth, mapping yearly dietary changes, as well as possible stress episodes in an individual's life throughout the formation process of the tooth.

Incremental dentine analysis operates on the same principles as carbon and nitrogen analysis from bulk collagen. In archaeological studies, δ^{13}C values are mainly used to differentiate between food-chains based on terrestrial plants with different photosynthetic pathways (i.e., C_4 plants, found primarily in tropical regions, and C_3 plants, which grow worldwide), as well as marine diets. It has been calculated that a mixed terrestrial and marine diet in humans will yield δ^{13}C values between −12‰ (purely marine) and −20.0‰ (purely terrestrial) (Schwarcz and Schoeninger 1991). This is based on previous studies of mean δ^{13}C values in C_3 plants (Bender 1968; O'Leary 1988) and marine resources (Tauber 1981; Chisholm *et al*. 1982; Wada *et al*. 1993), and their relationship with the consumer (Tieszen *et al*. 1983; Tauber 1986; Schwarcz and Schoeninger 1991; Ambrose and Norr 1993).

Stable nitrogen isotope values in plant and animal tissues vary depending on their trophic level. Starting at 0‰, the value is enriched by 3–6‰ in each successive level (Minagawa and Wada 1984; Schoeninger and DeNiro 1984), depending on various factors, including potentially differential enrichment in animals and humans, the composition of the diet, manuring of crops and individual metabolism (Haubert *et al*. 2005; Bogaard *et al*. 2007; Hedges and Reynard 2007).

Although δ^{13}C and δ^{15}N values are good indicators of diet, several physiological factors influence them. This makes incremental dentine analysis a method that can detect more than just dietary changes. In humans, more positive δ^{15}N values are generally more consistent with a higher percentage of animal protein in the diet (O'Connell and Hedges 1999; Ambrose *et al*. 2003). An increase in δ^{15}N values, however, is also associated with physiological and nutritional stress, including rapid growth, illness or malnutrition, whereby the body uses its own nitrogen reserves (Hobson *et al*. 1993; Katzenberg and Lovell 1999; Kalhan 2000; Gannes *et al*. 1997; Mekota *et al*. 2006), and breastfeeding (Fogel *et al*. 1989; Fuller *et al*. 2006). Decreasing δ^{15}N values have been associated with growth and development, whereby less nitrogen is excreted from the body than is taken in (Hobson and Clark 1992; Waters-Rist and Katzenberg 2010). Finally, a fall in δ^{13}C values can be indicative of severe nutritional stress, whereby the body accesses its internal fat stores, as demonstrated both in humans and birds (e.g., Cherel *et al*. 2005; Mekota *et al*. 2006).

For this research, a key purpose of this paper was to look for any diet or stress-related changes before death, which is why incremental dentine analysis was employed. In particular, the idea was to explore whether these changes were present in children who had died during a purported famine and were buried in one, or both, MG. For this reason, only teeth that were still in the process of formation at the time of the person's death were selected. The aim of this study was to document diet in non-adult individuals from the early months of their lives to their deaths from all three contexts. The objective was to compare their individual life histories and possible differences in diet.

The main hypotheses addressed were:

- That children from populations in Riga and nearby rural regions accessed available food resources differentially, especially marine and terrestrial protein, which would be expressed as detectable differences in incremental dentine profiles if there are rural immigrants in the MG.

- That if one, or both, MG contain the victims of a famine, then the diet of the affected children, as expressed in isotopic values, is expected to have changed not long before death in most of these individuals, while any evidence of change should be more varied in children who passed away from other causes.

This research is a new contribution to emerging evidence for childhood diet in past populations, using newly developed methods that focus on incremental dentine analysis. Moreover, studies of known victims of famine are currently very rare and obtaining new data provides a useful reference for future research exploring nutritional stress as expressed in incremental dentine δ^{13}C and δ^{15}N profiles.

MATERIALS AND METHODS

Materials

In total, 721 individuals were excavated from St Gertrude cemetery; 285 of them were non-adults (0–17 years old). There were 190 children in the general cemetery (GC), 55 in the south-eastern mass grave (MG1) and 40 in the north-western mass grave (MG2). Fewer than 10% of children buried in the MGs were prematurely born, compared with almost 20% in the GC; likewise, while 40% of children in the GC were aged between 1 and 6 years, only half as many individuals of a similar age were found in MG (Petersone-Gordina *et al*. 2018).

Radiocarbon analysis was carried out at the Oxford Radiocarbon Accelerator Unit (ORAU) on three individuals from the MG and one from the GC to establish the dates of the different contexts. The results confirmed that the first burials in the cemetery took place in the 15th century, while both MGs date from the 17th century, although not necessarily the same year (see Tables S1 and S2 and Fig. S1 in the additional supporting information).

Previously acquired adult carbon and nitrogen isotope values were used for comparative purposes for the non-adult population analysed here (see Table S3 in the additional supporting information) (Petersone-Gordina *et al*. 2018). All adult mean isotope data are presented with 2 SD (standard deviations) throughout this paper.

Methods

Individuals for dentine incremental collagen isotope analysis were selected according to age, whereby upper or lower permanent canines had at least one-third of their roots present, or the apex of the root was still open (between 7.0 and 14.5 years, according to AlQahtani *et al*. 2010), and by the preservation of the tooth—only individuals with post-mortem damage to the jaw , where the tooth was loose or could be removed without any damage to the alveolar bone, were selected.

Twelve non-adult individuals from the two MGs (six from each) matched the selection criteria. Only five individuals from the GC with at least one permanent canine met the requirements for this study; to increase the sample size, a lower second incisor and a lower second premolar from two individuals of a similar age were also selected from this context (see Table S4 in the additional supporting information).

There was no, or very little, dental wear on the selected teeth, resulting in fully preserved dentine starting from the first increment. Each dentinal increment was assigned an approximate age following the method of Beaumont and Montgomery (2015). The teeth were prepared for collagen extraction as described by (Beaumont *et al*. 2013; from Kirsanow *et al*. 2008), using Method 2.

Collagen samples of approximately 0.4 mg were weighed into tin capsules and measured in duplicate using a Costech Elemental Analyser (ECS 4010) connected to a Thermo Scientific Delta V Advantage isotope ratio mass spectrometer. Duplicates were analysed in the same run. Carbon isotope ratios were corrected for ^{17}O contribution and reported in standard delta (δ) notation in per mil (‰) relative to Vienna Pee Dee Belemnite (VPDB). Isotopic accuracy was monitored through routine analyses of in-house standards, which were stringently calibrated against international standards (e.g., USGS 40, USGS 24, IAEA 600, IAEA CH3, IAEA CH7, IAEA N1 and IAEA N2); this provides a total linear range in δ^{13}C between −46‰ and 3‰, and between −4.5‰ and 20.4‰ for δ^{15}N. Analytical uncertainty in δ^{13}C and δ^{15}N is typically ±0.1‰ or better for replicate analyses of the international standards and < 0.2‰ for replicate sample analysis. The charts show an error bar at 0.2‰. Total organic carbon and nitrogen were obtained as part of the isotopic analysis using an internal standard (glutamic acid, C = 40.82%, N = 9.52%).

For comparison of values, 2 SD of the analytical uncertainty (±0.4‰) were used. An overlap at 2 SD provides a conservative test of difference approximately equivalent to a *p*-value of 0.5% for normally distributed errors (Payton *et al*. 2003). While this method is not statistically exact, it is a simple and robust visual method that provides some compensation for Type I errors arising from the use of multiple comparisons in sequential isotope data, and the over-interpretation of analytical variability as a biogenic signal.

RESULTS

Collagen yields for each tooth were > 15%, with atomic ratios between 3.1 and 3.4, which is comparable with previous studies of incremental dentine collagen (Beaumont *et al*. 2013) and thus indicated sufficient well-preserved collagen (DeNiro 1985; van Klinken 1999), given that modern dentine is about 18% collagen by weight (Veis 1989). For detailed results of the isotope analysis, see Table S6 in the additional supporting information. The resulting number of increments, and duration of their formation, are shown in Table S4.

Non-adult mean incremental δ^{13}C values ranged from −21.1‰ (GC134) to −19.2‰ (MG2_508), and mean δ^{15}N values from 10.1‰ (MG1_156) to 13.4‰ (MG2_508), revealing

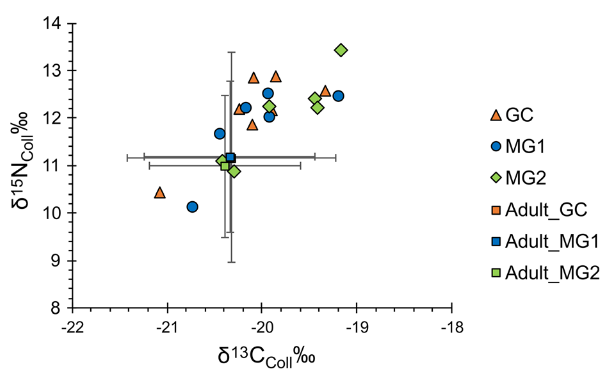

Figure 2 *Mean incremental dentine, and adult bone δ^{13}C and δ^{15}N values (±2 SD). GC, general cemetery; MG, mass grave. [Colour figure can be viewed at wileyonlinelibrary.com]*

high individual, rather than intercontextual, variability (see Fig. 2 and Table S5 in the additional supporting information). Mean incremental dentine and adult bone δ^{13}C and δ^{15}N values for individuals from all contexts overlapped within 2 SD.

In the GC, variations in δ^{13}C profiles only exceeded 2 SD of analytical error (±0.4‰) in individual GC12, whereby the value decreased by 1‰ between the ages of 4.1 and 6.5 years (Fig. 3). Although not exceeding 2 SD of analytical error, a progressive decline in values between the ages of 0.6 and 4.5 years was observed in individuals GC134 and GC615; this might be relevant in light of a similar, albeit significant, decrease in the δ^{15}N profiles of both individuals between the same ages (see below). Most of the incremental δ^{13}C values of individual GC134 did not overlap with those of other children from this context between the ages of 4.5 and 12.2 years, within 2 SD of analytical error.

The first δ^{15}N values of GC63 and GC615 were higher than the adult mean (11.2 ± 2.2‰) (Fig. 3). The profiles of both individuals decreased by 2.4‰ and 3.1‰ until the ages of 3.5 and 4.6 years, respectively, exceeding 2 SD of analytical error. The first period of decline in GC615 was mimicked by the δ^{13}C profile.

A progressive decrease in δ^{15}N values from the first increment onwards, which exceeded 2 SD of analytical error, was also observed in individuals GC12 and GC134. In GC12, the value decreased by 1.6‰ until the age of 6.5 years, and the δ^{15}N profile of GC134 decreased by 1.9‰ until 4.5 years. The initial δ^{15}N values of GC134 were lower than in other individuals and did not overlap with any other profile (±0.4‰) between the ages of 1.9 and 5.8 years (Fig. 3).

The δ^{15}N profile of individual GC41 increased by 2.4‰ between the ages of 2.0 and 3.0 years (from 11.5‰ to 13.9‰, ±0.4), and decreased again by 2.9‰ between the ages of 5.1 and 7.2 years (from 13.7‰ to 10.8‰, ±0.4). Between the ages of 7.2 and 12.5 years, a progressive rise in δ^{15}N was observed, reaching 12.5‰ at the end of this period. The value decreased again in the last two years of life by 1.2‰, exceeding 2 SD of analytical error by 0.4‰. These changes were mirrored by the δ^{13}C profile, albeit without exceeding 2 SD of analytical error. The covariation of both profiles was significant ($r = 0.7$; $r^2 = 0.5$; $p = 0.004$; d.f. = 12; $t = 3{,}43$) (Fig. 4).

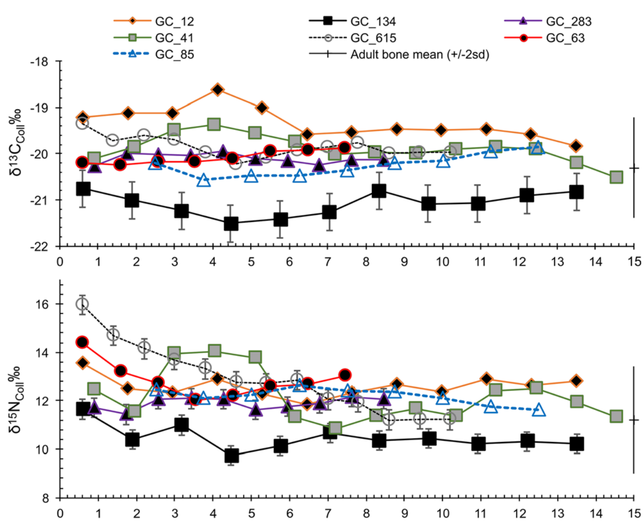

Figure 3 *δ^{13}C and δ^{15}N profiles of seven individuals from the general cemetery (GC). The profile of GC134 shows 2 SD of analytical error for each increment (±0.4). [Colour figure can be viewed at wileyonlinelibrary.com]*

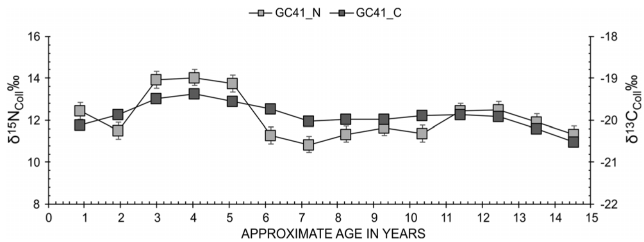

Figure 4 *δ^{13}C and δ^{15}N values against age in individual GC41 from the general cemetery (GC), showing significant covariation.*

In three of six children from MG1, variation in δ^{13}C profiles exceeded 2 SD of analytical error (Fig. 5). In MG1_83, a progressive rise was observed throughout their whole life, from −21.2‰ at 0.6, to −19.8‰ at 10.2 years of age. The δ^{13}C profile of MG1_630 showed a pronounced decrease in the first three increments, between 0.9 and 2.3 years of age, whereby the values changed by 1.1‰. This was regarded as significant in light of similar changes in δ^{15}N profile. Despite the lack of significant changes, the profile of MG1_127 was higher than those of other children, exceeding 2 SD of analytical error in the second and last increments.

In individuals MG1_497, MG1_627 and MG1_630, the first incremental δ^{15}N values were above the mean adult bone value (11.2 ± 1.6‰), but the rest of their profiles were consistent with it (Fig. 5).

In MG1_497, the δ^{15}N value dropped by 2.1‰ between the ages of 0.6 and 1.5 years, after which the profile remained stable until shortly before death, when an increase by 1.6‰ was observed between the last two increments (12.6 and 13.5 years of age). In individual MG1_627, a continuous decline by 1.5‰ was observed between the first and fifth increments, and ages of 0.9 and 3.9 years. The first δ^{15}N value of MG1_630 was the highest in this context at 15.1‰ and dropped by 3.6‰ in the two following increments, until the age of 2.3 years. After the drop,

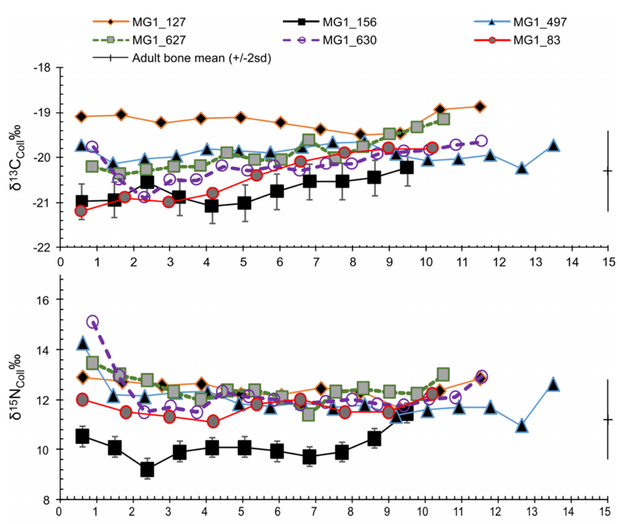

Figure 5 *δ^{13}C and δ^{15}N profiles of six individuals from mass grave MG1. The profile of MG1_156 shows 2 SD of measurement error for each increment (±0.4). [Colour figure can be viewed at wileyonlinelibrary.com]* no significant changes were observed until the age of 9.4 years, when the value increased by 1.2‰ in four consecutive increments until the person's age at death at 11.5 years. In MG1_127, there was a rise in the last three increments by 1.2‰ between the ages of 9.3 and 11.5 years. The δ^{15}N profile of MG1_156 remained lower than those of other individuals, exceeding analytical uncertainty in all increments, except the last. In the first three increments, representing the ages of 0.6 and 2.5 years, the value decreased by 1.3‰. This was followed by a long period of insignificant changes until the age of 6.8 years, when a progressive increase of 1.8‰ was observed until the person's age at death at 9.5 years.The δ^{13}C values of MG2_508 rose above the adult mean (−20.4 ± 0.8‰) at 5.8 years of age and remained so until death at 8.5 years (Fig. 6). The δ^{13}C profiles of individuals MG2_177 and MG2_432 resembled that of MG1_127 in terms of insignificant changes, and similarly high δ^{13}C values. In MG2_103, the δ^{13}C value decreased by 1‰ between 0.6 and 3.1 years of age. This was mirrored by the δ^{15}N profile (see below). The value then progressively increased in the second to last increment at 9.6 years of age (−19.5‰), reaching its highest point and the same value found at 0.6 years.

The profiles of MG2_516 and MG2_606 had lower δ^{13}C values than those for most other children, except MG2_103, exceeding 2 SD of analytical error from 0.9 to around 6 years of age in both individuals. In MG2_516, the δ^{13}C value progressively increased by 1.2‰ between the ages of 4.9 and 9.7 years, until the second to last increment. This change exceeded 2 SD of analytical error and was similar to the profile of MG1_83, discussed above. In MG2_606, after a period of insignificant change between 0.9 and 5.3 years, the value increased by 1.2‰ in two consecutive increments until 7.6 years, and this was mirrored by a rise in δ^{15}N values. In both, MG2_516 and MG2_606, after the period of increased values, the profiles overlapped with those of other children within 2 SD of analytical error.

The δ^{15}N profile of MG2_508 only overlapped with the adult value (11.0 ± 1.5‰) at the age of 5.9 years, but remained higher for all other increments (Fig. 6), consistent with the child's higher δ^{13}C profile. The δ^{15}N value declined by 1.9‰ in the first three increments, representing ages between 0.9 and 3.4 years. The first δ^{15}N value for MG2_103 was the highest in this context. In the three following increments, it dropped by 4.4‰, and remained without significant changes

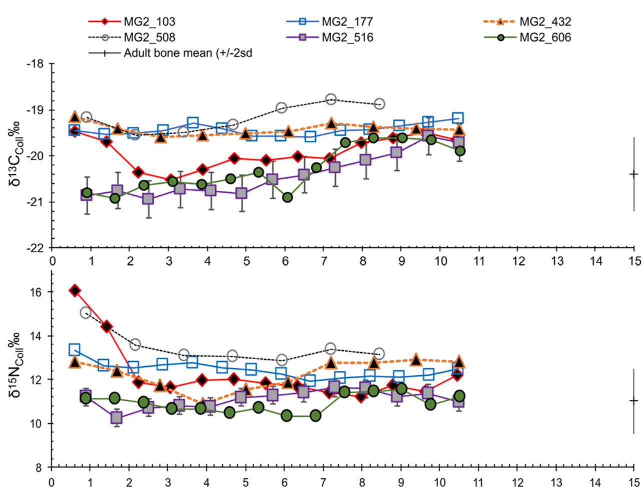

Figure 6 *δ^{13}C and δ^{15}N profiles of six individuals from mass grave MG2. The profile of MG2_516 shows 2 SD of analytical error for each increment (±0.4). [Colour figure can be viewed at wileyonlinelibrary.com]* throughout the rest of this child's life, regardless of the continuous rise of the δ^{13}C profile after this age. The profile reached the adult mean bone value between the ages of 1.4 and 2.2 years. In MG2_432, the δ^{15}N value decreased by 1.9‰ between 0.6 and 3.9 years, and then increased again until the age of 7.2 years, reaching the first incremental value. The changes exceeded 2 SD of analytical error and were not consistent with the flat δ^{13}C profile of this individual. In MG2_516, the δ^{15}N value decreased by 1‰ between the first and second increments, and then increased by 1.4‰ by the age of 7.3 years, mirroring the δ^{13}C profile. Finally, in MG2_606, changes in the δ^{15}N profile also corresponded to those observed in the δ^{13}C profile, whereby after a period of little variation, the value increased by 1.1‰ between 6.8 and 7.6 years of age.

DISCUSSION

Interpretation of the observed δ^{13}C and δ^{15}N values

Based on the above discussion, the observed mean non-adult δ^{13}C values (between −19.2‰ and −21.1‰) indicate a mainly terrestrial diet based on C_3 plants, with some marine input for most individuals. It has to be taken into account that δ^{13}C values correlate with salinity, which could cause the end value of a marine component in the diet of past people around the Baltic Sea to be as low as −15‰ if the marine source was mainly the Baltic Sea (Strain and Tan 1979; Lidén and Nelson 1994). This is because the salinity of the Baltic Sea can range between 7‰ and 25‰, compared with 35‰ in other oceans (Westman *et al.* 1999; Robson *et al.* 2016). While most archaeological marine fish δ^{13}C values from the Baltic Sea range between −7.8‰ and −16.6‰ (Antanaitis-Jacobs *et al.* 2009; Robson *et al.* 2016), Eastern Baltic cod (*G. morhua callarias*) has yielded values as high as −18.6‰ (Barrett *et al.* 2011; Orton *et al.* 2011). This has been explained by the lower salinity of the Eastern Baltic Sea, and the limited natural movement of cod between different regions of the sea (Barrett *et al.* 2011; Orton *et al.* 2011; Bagge *et al.* 1994). Accordingly, the variation in isotope values of marine fish from the Baltic Sea might have implications for human dietary isotope values, depending on what fish species dominated in the diet of these individuals. Mean δ^{15}N values in the non-adult individuals studied here were between 10.1‰ and 13.4‰. The factors that might have influenced them in this population are discussed below.

The overlap of mean δ^{13}C and δ^{15}N dentine values in children from all three contexts with those of mean adult bone values were consistent with previous research, and suggests that there were no significant dietary differences between the contexts in terms of access to resources. Individual profiles of children, however, varied within each context, and will be discussed in detail below to explore the similarities and differences between them.

Similarities and differences in dietary profiles within each burial context

General cemetery In the GC, the δ^{13}C profiles were relatively flat, indicating little change in the diet throughout childhood in most individuals, except GC12, whereby the decline in both values indicates a reduction in marine resources between the ages of 4 and 6.5 years. The lower δ^{13}C and δ^{15}N values of individual GC134 indicate a diet with less marine input than in other children from this context and might suggest that the child either lived in an area where marine fish were not available, or had different dietary preferences, while living in the same community. The changes in δ^{13}C and δ^{15}N profiles of GC41 were unlike those of any other individual in the cemetery. The sudden increase and decrease in both values, especially δ^{15}N between 2 and 7 years of age, might indicate an increase in the marine proportion of the diet, although a period of nutritional stress cannot be excluded, since the changes in δ^{13}C profile were not significant. It is possible that the differences in diet observed until the age of 7 years in this child, compared with the other children from the GC, might be due to a different origin, and this possibility is being explored further by strontium isotope analysis. The similarity of the rest of the profile with those of other children from the GC, however, suggests that by the time of death, this child had been a resident of Riga, or indeed Gertrude village, for at least seven years.

Mass graves The profiles of most children in both MGs showed greater variation and are difficult to interpret in terms of the different population groups. The lower δ^{15}N profile of MG1_156 indicates a lower proportion of terrestrial animal and/or marine protein in the diet, but all δ^{15}N values of this individual remained within the adult mean, and thus they might represent individual dietary variation. Likewise, the higher δ^{13}C and δ^{15}N profiles of MG2_508, compared with the adult mean, might not be significant in the light of overlapping values with several other children from this context.

The results showed that the δ^{13}C values of MG1_103 and MG2_630, and MG1_83 and MG2_516, changed in the same way from the first to the last increments. Likewise, the profiles of MG1_127, MG2_177 and MG2_432 were also similar (see Fig. S2 in the additional supporting information). Since δ^{13}C is not influenced by physiological processes to the same extent as δ^{15}N, as discussed above, these profile patterns suggest similar diets for these groups of individuals. This, in turn, points to the probability that both MGs contained some children from the same communities.

So far, there is no evidence for similar δ^{13}C profiles for children who were buried in either of the MGs and the GC. This partly supports the first hypothesis that there would be detectable differences in incremental dentine profiles of individuals from Riga and other regions. This suggests that while people living in Riga and in rural areas along the coastline, or with good trade links to the coastline, had access to similar resources, they were used differentially by each community, or even each family, based on the substantial differences found in individual profiles in all contexts, and in the MGs in particular.

Victims of the famine of 1601–02

Four of the six children from MG1 (MG1_127, MG1_156, MG1_497 and MG1_630) showed an increase in their δ^{15}N values before death, without corresponding changes in δ^{13}C values. The rise occurred after a period of relative stability in the profiles of all four individuals, and the changes appear to be representative of a collective experience that took place at the same time, given that these individuals likely died within days, or weeks, of each other. The changes occurring over one to two years before death could represent the prolonged food shortage experienced at the beginning of the 17th century, and it is therefore possible that MG1 contains victims of the famine of 1601–02.

Similar changes in δ^{15}N values have been reported in individuals from other cemetery populations who are known to have experienced nutritional stress, including the victims of the mid-19th century Great Irish Famine (Beaumont *et al*. 2015; Beaumont and Montgomery 2016), and people living in the Neolithic period on the Shetland Islands of Scotland (Montgomery *et al*. 2013). However, the absence of an increase in δ^{15}N values in the other two individuals from MG1 does not mean that the famine did not affect them. The facilities provided for the immigrants, as discussed above, might have provided adequate nutrition, especially for those who arrived early and only experienced a brief, if any, period of undernutrition. The shelter and food, however, did not necessarily protect them from the cold and infections such as typhus and dysentery, which occur in overcrowded, unhygienic environments, and are exacerbated by a weakened immune system (Dirks *et al*. 1980; World Health Organization (WHO) 2002). A rapid death from infection in children who received adequate nutrition throughout the famine would therefore not leave any trace of nutritional stress in their isotopic profiles.

None of the δ^{15}N profiles of children from MG2 exhibited changes towards the end of their lives. This is consistent with rapid death, probably due to an epidemic. As discussed above, there were two plague epidemics in the first half of the 17th century. Historical sources suggest that people from rural areas came to Riga not only during the famine of 1601–02 but also as a result of other hardships. For many, the main reason for coming to the city was the prospect of burial, because this was no longer possible in their homeland due to the scarcity of a population to bury their dead (Napiersky, 1890). This would explain the presence of children from the same communities in both MGs, if their deaths relate to two different historical events, as also supported by the results of radiocarbon dating.

Origin of the children in the MG

The variation in individual dietary profiles of children from the MGs, as opposed to more similar, flat, patterns observed in the GC, points to the possibility that the children from the MGs represent different communities, while most of those buried in the GC were from Gertrude village, or its vicinity. The lack of comparative evidence from other rural populations from Latvia, however, makes identification of a typical biological rural profile difficult. Incremental dentine analysis using data from contemporary rural populations would be necessary to develop this argument, and to explore further possible differences in the diet of urban and rural populations, as well as childhood diets in post-medieval Latvia.

As shown by relatively few changes in both δ^{13}C and δ^{15}N profiles of children from the GC, these individuals represent a population group with a mostly constant access to food resources, although the cemetery was in use for over three centuries. Children from each MG, however, represent the same generation, albeit one that experienced several hardships during their lifetime, as expressed in evidence for physiological stress very early in the lives of several individuals (see below), and at the end of life in four people from MG1. There remains a possibility that changes in diet during the hardships could be expressed in different isotopic profiles of the generation who experienced them, even if all the people buried in St Gertrude's cemetery derived from the same, local, population. Moreover, the famine of 1601–02, as well as outbreaks of plague, affected the whole region, including Riga, and some victims were buried in St Gertrude's cemetery, as mentioned above. To explore further the possible origin of the people from the MG, a pilot study using strontium isotope analysis is in progress.

Differences in the initial δ^{15}N values and profile patterns

Finally, in all contexts, the first δ^{15}N values of some children were higher than the adult mean. High initial δ^{15}N values have often been interpreted as a signal of breastfeeding, since breastfed infants are a trophic level (2–3‰) above their mothers or wet-nurses (Fogel *et al*. 1989; Wright and Schwarcz 1999; Fuller *et al*. 2006). Consequently, a drop in δ^{15}N values has been interpreted as a signal of weaning, whereby the introduction of solid foods causes a negative trophic level shift (Dupras *et al*. 2001; Fuller *et al*. 2003; Eerkens *et al*. 2011). All but one tooth analysed in this research began forming before the age of one year, and it is possible that they reflect both the period of exclusive breastfeeding and the period of weaning. Evidence gathered from folklore and ethnographic studies from 19th–early 20th-century Latvia suggests that children were not completely weaned until one or two years of age (Muktupāvela 2005).

There is increasing evidence, however, that the reasons behind high initial δ^{15}N values are far more complex. For example, Beaumont *et al*. (2015) have argued that high δ^{15}N values have been found in infants too young to have been breastfed at the age of their deaths (Richards *et al*. 2002; Kinaston *et al*. 2009, Nitsch *et al*. 2011), and might therefore represent *in utero* δ^{15}N values, which are influenced by changes in the mother's diet and physiology during pregnancy (Fuller *et al*. 2004). A high neonatal δ^{15}N would rise even higher during breastfeeding; conversely, in well-nourished infants with a low δ^{15}N at birth, the increase during breastfeeding will be small and might be undetectable using incremental dentine analysis (Beaumont *et al*. 2015). This phenomenon has also been observed in other recent incremental dentine studies (King *et al*. 2017; Beaumont *et al*. 2018) and requires further research.

To interpret a decline in initial δ^{15}N values as a possible signal of weaning, a similar change in δ^{13}C values should be observed, because a rise of δ^{13}C values by approximately 1‰ has been reported during breastfeeding (Katzenberg *et al*. 1993; Wright and Schwarcz 1999; Fuller *et al*. 2006). Consequently, it is possible that the high first incremental δ^{15}N values of GC63, GC615, MG1_497, MG1_627, MG1_630, and MG2_103 and MG2_508 are consistent with *in utero* stress. In individuals GC615, MG1_630 and MG2_103, where both δ^{15}N and δ^{13}C profiles decreased in the following increments, the changes might represent weaning. In other individuals, where the δ^{15}N value decreased without corresponding changes in δ^{13}C, this might be due to growth and development, as discussed above. Weaning and/or growth might also explain initial profiles of individuals in which a decline in both, or only δ^{15}N, values was observed at the beginning of life, albeit without δ^{15}N values exceeding the adult mean.

CONCLUSIONS

Overall, the results of this research support both hypotheses, which predicted the observed similarities of individual profiles of several children from both MGs, but not between the MGs and the GC, and also the evidence for nutritional stress shortly before death in four individuals from MG1. On the other hand, even though the profiles were different in children from the MGs and the GC, the means of the whole population were similar. This suggests that if there were different population groups buried in St Gertrude's cemetery, all had access to similar food resources, but used them differentially, and probably not only by each community but also by individual family groups.

The small sample size, and the lack of comparative data from other contemporary rural and urban cemetery populations in Latvia and elsewhere, limits the identification of rural immigrants in the cemetery. Accordingly, differences in profiles of children from the MGs might simply represent different dietary strategies during the hardships that these children experienced which eventually caused their deaths, according to both historical sources and isotopic evidence gathered during this research.

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REFERENCES

Actiņš, A., Lūsēns, M., Rudoviča, V., Vīksna, A., and Zariņa, G., 2009, Rīgas Sv. Ģertrūdes baznīcas kapsētas augsnes paraugu ķīmiskā sastāva izpēte [chemical composition of soil samples from St Gertrude cemetery], in *Senā Rīga 6: pilsētas arheoloija, arhitektūra un vēsture* (eds. I. Bebre, M. Barzdeviča, A. Celmiņš, G. Gerhards, and G. Zariņa), 59–70, Mantojums, Riga.

AlQahtani, S. J., Hector, M. P., and Liversidge, H. M., 2010, Brief communication: The London atlas of human tooth development and eruption, *American Journal of Physical Anthropology*, **142**, 481–90.

Ambrose, S. H., Buikstra, J., and Krueger, H. W., 2003, Status and gender differences in diet at mound 72, Cahokia, revealed by isotopic analysis of bone, *Journal of Anthropological Archaeology*, **22**, 217–26.

Ambrose, S. H., and Norr, L., 1993, Experimental evidence for the relationship of the carbon isotope ratios of whole diet and dietary protein to those of bone collagen and carbonate, in *Prehistoric human bone* (eds. J. B. Lambert and G. Grupe), 1–37, Springer, Berlin.

Antanaitis-Jacobs, I., Richards, M., Daugnora, L., Jankauskas, R., and Orginc, N., 2009, Diet in early Lithuanian prehistory and the new stable isotope evidence, *Archaeologia Baltica*, **12**, 12–30.

Bagge, O., Thurow, F., Steffensen, E., and Bay, J., 1994, The Baltic cod, *Dana*, **10**, 1–28.

Barrett, J. H., Orton, D., Johnstone, C., Harland, J., Van Neer, W., Ervynck, A., Roberts, C., Locker, A., Amundsen, C., Enghoff, I. B., Hamilton-Dyer, S., Heinrich, D., Hufthammer, A. K., Jones, A. K. G., Jonsson, L., Makowiecki, D., Pope, P., O'Connell, T. C., de Roo, T., and Richards, M., 2011, Interpreting the expansion of sea fishing in medieval Europe using stable isotope analysis of archaeological cod bones, *Journal of Archaeological Science*, **38**, 1516–24.

Beaumont, J., Atkins, E. C., Buckberry, J., Haydock, H., Horne, P., Howcroft, R., Mackenzie, K., and Montgomery, J., 2018, Comparing apples and oranges: Why infant bone collagen may not reflect dietary intake in the same way as dentine collagen, *American Journal of Physical Anthropology*, **167**, 524–40.

Beaumont, J., Gledhill, A., Lee-Thorp, J., and Montgomery, J., 2013, Childhood diet: A closer examination of the evidence from dental tissues using stable isotope analysis of incremental human dentine, *Archaeometry*, **55**, 277–95.

Beaumont, J., and Montgomery, J., 2015, Oral histories: A simple method of assigning chronological age to isotopic values from human dentine collagen, *Annals of Human Biology*, **42**, 407–14.

Beaumont, J., and Montgomery, J., 2016, The great Irish famine: Identifying starvation in the tissues of victims using stable isotope analysis of bone and incremental dentine collagen, *PLoS ONE*, **11**, e0160065.

Beaumont, J., Montgomery, J., Buckberry, J., and Jay, M., 2015, Infant mortality and isotopic complexity: New approaches to stress, maternal health, and weaning, *American Journal of Physical Anthropology*, **157**, 441–57.

Bender, M. M., 1968, Mass spectrometric studies of carbon 13 variations in corn and other grasses, *Radiocarbon*, **10**, 468–72.

Bogaard, A., Heaton, T. H. E., Poulton, P., and Merbach, I., 2007, The impact of manuring on nitrogen isotope ratios in cereals: Archaeological implications for reconstruction of diet and crop management practices, *Journal of Archaeological Science*, **34**, 335–43.

Cherel, Y., Hobson, K. A., Bailleul, F., and Groscolas, R., 2005, Nutrition, physiology, and stable isotopes: New information from fasting and molting penguins, *Ecology*, **86**, 2881–8.

Chisholm, B. S., Nelson, D. E., and Schwarcz, H. P., 1982, Stable-carbon isotope ratios as a measure of marine versus terrestrial protein in ancient diets, *Science*, **216**, 1131–2.

Das Buch der Aeltermänner grosser Gilde von 1540–1611 1844. Monumenta Livoniae Antiqua. Riga: Eduard Frantzen's Verlags-Comptoir.

Dean, M. C., and Scandrett, A. E., 1995, Rates of dentine mineralization in permanent human teeth, *International Journal of Osteoarchaeology*, **5**, 349–58.

DeNiro, M. J., 1985, Postmortem preservation and alteration of in vivo bone collagen isotope ratios in relation to palaeodietary reconstruction, *Nature*, **317**, 806–9.

Dirks, R., Armelagos, G. J., Bishop, C. A., Brady, I. A., Brun, T., Copans, J., Doherty, V. S., Fraňková, S., Greene, L. S., and Jelliffe, D. B., 1980, Social responses during severe food shortages and famine [and comments and reply], *Current Anthropology*, **21**, 21–44.

Dunsdorfs, E., 1962, *Latvijas Vēsture, 1600–1710 [history of Latvia]*, Daugava, Stockholm.

Dupras, T. L., Schwarcz, H. P., and Fairgrieve, S. I., 2001, Infant feeding and weaning practices in Roman Egypt, *American Journal of Physical Anthropology*, **115**, 204–12.

Eerkens, J. W., Berget, A. G., and Bartelink, E. J., 2011, Estimating weaning and early childhood diet from serial microsamples of dentin collagen, *Journal of Archaeological Science*, **38**, 3101–11.

Fogel, M. L., Tuross, N., and Owsley, D. W., 1989, Nitrogen isotope tracers of human lactation in modern and archaeological populations, *Carnegie Institution of Washington Yearbook*, **88**, 111–17.

Fuller, B. T., Fuller, J. L., Harris, D. A., and Hedges, R. E., 2006, Detection of breastfeeding and weaning in modern human infants with carbon and nitrogen stable isotope ratios, *American Journal of Physical Anthropology*, **129**, 279–93.

Fuller, B. T., Fuller, J. L., Sage, N. E., Harris, D. A., O'Connell, T. C., and Hedges, R. E., 2004, Nitrogen balance and δ^{15}N: Why you're not what you eat during pregnancy, *Rapid Communications in Mass Spectrometry*, **18**, 2889–96.

Fuller, B. T., Richards, M. P., and Mays, S. A., 2003, Stable carbon and nitrogen isotope variations in tooth dentine serial sections from Wharram Percy, *Journal of Archaeological Science*, **30**, 1673–84.

Gannes, L. Z., O'Brien, D. M., and del Rio, C. M., 1997, Stable isotopes in animal ecology: Assumptions, caveats, and a call for more laboratory experiments, *Ecology*, **78**(4), 1271–6.

Haubert, D., Langel, R., Scheu, S., and Ruess, L., 2005, Effects of food quality, starvation and life stage on stable isotope fractionation in Collembola, *Pedobiologia*, **49**, 229–37.

Hedges, R. E. M., and Reynard, L. M., 2007, Nitrogen isotopes and the trophic level of humans in archaeology, *Journal of Archaeological Science*, **34**, 1240–51.

Hobson, K. A., Alisauskas, R. T., and Clark, R. G., 1993, Stable-nitrogen isotope enrichment in avian tissues due to fasting and nutritional stress: Implications for isotopic analyses of diet, *The Condor*, **95**(2), 388–94.

Hobson, K. A., and Clark, R. G., 1992, Assessing avian diets using stable isotopes II: Factors influencing diet-tissue fractionation, *Condor*, **94**, 189–97.

Kalhan, S. C., 2000, Protein metabolism in pregnancy, *The American Journal of Clinical Nutrition*, **71**, 1249s–1255s.

Katzenberg, M. A., and Lovell, N. C., 1999, Stable isotope variation in pathological bone, *International Journal of Osteoarchaeology*, **9**, 316–24.

Katzenberg, M. A., Saunders, S. R., and Fitzgerald, W. R., 1993, Age differences in stable carbon and nitrogen isotope ratios in a population of prehistoric maize horticulturists, *American Journal of Physical Anthropology*, **90**, 267–81.

Kinaston, R. L., Buckley, H. R., Halcrow, S. E., Spriggs, M. J. T., Bedford, S., Neal, K., and Gray, A., 2009, Investigating foetal and perinatal mortality in prehistoric skeletal samples: A case study from a 3000-year-old Pacific Island cemetery site, *Journal of Archaeological Science*, **36**, 2780–7.

King, C. L., Millard, A. R., Gröcke, D. R., Standen, V. G., Arriaza, B. T., and Halcrow, S. E., 2017, A comparison of using bulk and incremental isotopic analyses to establish weaning practices in the past, *STAR: Science & Technology of Archaeological Research*, **3**(1), 126–34.

Kirsanow, K., Makarewicz, C., and Tuross, N., 2008, Stable oxygen (δ^{18}O) and hydrogen (δD) isotopes in ovicaprid dentinal collagen record seasonal variation, *Journal of Archaeological Science*, **35**, 3159–67.

Lidén, K., and Nelson, E. D., 1994, Stable carbon isotopes as dietary indicator, in the Baltic area, *Fornvännen*, **89**(1), 13–21.

Mekota, A. M., Grupe, G., Ufer, S., and Cuntz, U., 2006, Serial analysis of stable nitrogen and carbon isotopes in hair: Monitoring starvation and recovery phases of patients suffering from anorexia nervosa, *Rapid Communications in Mass Spectrometry*, **20**, 1604–10.

Minagawa, M., and Wada, E., 1984, Stepwise enrichment of ^{15}N along food chains: Further evidence and the relation between δ^{15}N and animal age, *Geochimica et Cosmochimica Acta*, **48**, 1135–40.

Montgomery, J., Beaumont, J., Jay, M., Keefe, K., Gledhill, A. R., Cook, G. T., Dockrill, S. J., and Melton, N. D., 2013, Strategic and sporadic marine consumption at the onset of the Neolithic: Increasing temporal resolution in the isotope evidence, *Antiquity*, **87**, 1060–72.

Muktupāvela, R., 2005, *Inkulturācijas figuratīvo formu salīdzinošā analīze [comparative analysis of figurative forms of inculturation]*, PhD, Latvian Academy of Culture.

Nanci, A., 2003, Dentin-pulp complex, in *Ten Cate's oral histology: Development, structure, and function* (ed. A. Nanci), 191–238, Mosby, Missouri.

Napiersky, J. G. L., 1890, *Bodeckers Chronik livländischer und rigascher Ereignisse, 1593–1638*, N. Kymmel's Buchhandlung, Riga.

Nitsch, E. K., Humphrey, L. T., and Hedges, R. E., 2011, Using stable isotope analysis to examine the effect of economic change on breastfeeding practices in Spitalfields, London, UK, *American Journal of Physical Anthropology*, **146**, 619–28.

Nyenstädt, F. 1837. *Franz Nyenstädt's Livländische Chronik*. Riga; Leipzig: Verlag von Eduard Frantzen's Buchhandlung.
O'Connell, T. C., and Hedges, R. E., 1999, Investigations into the effect of diet on modern human hair isotopic values, *American Journal of Physical Anthropology*, **108**, 409–25.
O'Leary, M. H., 1988, Carbon isotopes in photosynthesis, *Bioscience*, **38**, 328–36.
Orton, D. C., Makowiecki, D., de Roo, T., Johnstone, C., Harland, J., Jonsson, L., Heinrich, D., Enghoff, I. B., Lõugas, L., Van Neer, W., Ervynck, A., Hufthammer, A. K., Amundsen, C., Jones, A. K. G., Locker, A., Hamilton-Dyer, S., Pope, P., MacKenzie, B. R., Richards, M., O'Connell, T. C., and Barrett, J. H., 2011, Stable isotope evidence for late medieval (14th–15th C) origins of the eastern Baltic cod (Gadus morhua) fishery, *PLoS ONE*, **6**, e27568.
Payton, M. E., Greenstone, M. H., and Schenker, N., 2003, Overlapping confidence intervals or standard error intervals: What do they mean in terms of statistical significance? *Journal of Insect Science*, **3**(1), 34–8.
Petersone-Gordina, E., Roberts, C., Millard, A. R., Montgomery, J., and Gerhards, G., 2018, Dental disease and dietary isotopes of individuals from St Gertrude church cemetery, Riga, Latvia, *PLoS ONE*, **13**(1), e0191757.
Pīrangs, H. 1932. Rīgas kapsētas [graveyards of Riga]. *In:* Līventāls, T. S., Sadovska V. (ed.) *Rīga kā Latvijas galvas pilsēta*. Riga: Rīgas pilsētas valde, pp. 501–6.
Richards, M. P., Mays, S., and Fuller, B. T., 2002, Stable carbon and nitrogen isotope values of bone and teeth reflect weaning age at the medieval Wharram Percy site, Yorkshire, UK, *American Journal of Physical Anthropology*, **119**, 205–10.
Robson, H. K., Andersen, S. H., Clarke, L., Craig, O. E., Gron, K. J., Jones, A. K. G., Karsten, P., Milner, N., Price, T. D., and Ritchie, K., 2016, Carbon and nitrogen stable isotope values in freshwater, brackish and marine fish bone collagen from Mesolithic and Neolithic sites in central and northern Europe, *Environmental Archaeology*, **21**, 105–18.
Rusovs, B., 1926, *Livonijas kronika [Chronicle of Livonia]*, Valters un Rapa, Riga.
Schoeninger, M. J., and DeNiro, M. J., 1984, Nitrogen and carbon isotopic composition of bone collagen from marine and terrestrial animals, *Geochimica et Cosmochimica Acta*, **48**, 625–39.
Schwarcz, H. P., and Schoeninger, M. J., 1991, Stable isotope analyses in human nutritional ecology, *American Journal of Physical Anthropology*, **34**, 283–321.
Strain, P. M., and Tan, F. C., 1979, Carbon and oxygen isotope ratios in the Saguenay Fjord and the St Lawrence estuary and their implications for paleoenvironmental studies, *Estuarine and Coastal Marine Science*, **8**, 119–26.
Tauber, H., 1981, 13C evidence for dietary habits of prehistoric man in Denmark, *Nature*, **292**, 332–3.
Tauber, H. 1986. Analysis of stable isotopes in prehistoric populations. *In:* Hermann, B. (ed.) *Innovative trends in prehistoric anthropology* Berlin: Mitteilungen del Berliner Gesellschaft für Anthropologie, Ethnologie und Urgeschichte pp. 31–8.
Tieszen, L. L., Boutton, T. W., Tesdahl, K. G., and Slade, N. A., 1983, Fractionation and turnover of stable carbon isotopes in animal tissues: Implications for δ^{13}C analysis of diet, *Oecologia*, **57**, 32–7.
van Klinken, G. J., 1999, Bone collagen quality indicators for palaeodietary and radiocarbon measurements, *Journal of Archaeological Science*, **26**, 687–95.
Veis, A., 1989, Biochemical studies of vertebrate tooth mineralization, in *Biomineralization: Chemical and biochemical perspectives* (eds. S. Mann, J. Webb, and R. J. P. Williams), 189–222, VCH Publishers, New York.
Wada, E., Kabaya, Y., and Kurihara, Y., 1993, Stable isotopic structure of aquatic ecosystems, *Journal of Biosciences*, **18**, 483–99.
Waters-Rist, A. L., and Katzenberg, M. A., 2010, The effect of growth on stable nitrogen isotope ratios in subadult bone collagen, *International Journal of Osteoarchaeology*, **20**(2), 172–91.
Westman, P., Wastegård, S., Schoning, K., Gustafsson, B., and Omstedt, A., 1999, Salinity change in the Baltic Sea during the last 8500 years: Evidence, causes and models, in *SKB technical report TR-99-38*, Swedish Nuclear Fuel and Waste Management Co., Stockholm.
World Health Organization. 2002. *Control of communicable diseases and prevention of epidemics* [online]. Geneva: WHO. Available: www.who.int/entity/water_sanitation_health/hygiene/emergencies/em2002chap11.pdf.
Wright, L. E., and Schwarcz, H. P., 1999, Correspondence between stable carbon, oxygen and nitrogen isotopes in human tooth enamel and dentine: Infant diets at Kaminaljuyu, *Journal of Archaeological Science*, **26**, 1159–70.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1. Results of radiocarbon analysis on human bone samples.
Table S2. Calibrated radiocarbon dates assuming no marine input into the diet (all dates are CE) using OxCal 3.2 (Bronk Ramsey 2009) and IntCal13 (Reimer *et al.* 2013) and rounded out to the nearest 10 years according to the conventions of Millard (2014).
Table S3. Mean, minimum and maximum adult δ^{13}C (‰VPDB) and δ^{15}N (‰ AIR) values.
Table S4. Selected individuals, their age at death, tooth sample, number of increments, duration of increment formation for each tooth and the age of initial crown formation (C_i). Source: after AlQahtani *et al.*
Table S5. Mean incremental δ^{13}C and δ^{15}N values, ±2 SD.
Table S6. Incremental dentine δ^{13}C (‰VPDB) and δ^{15}N (‰AIR) values, percentage weight, C: N atomic ratios, types of teeth and age at death of each individual.

Figure S1. Results of radiocarbon analysis from MG1_645, MG1_488, MG2_687 and GC_676, assuming no marine input into the diet.

Figure S2. Similarity in δ^{13}C profiles of individuals MG1_630 and MG2_103, and MG1_83 and MG2_516, as well as MG2_432, MG1_127 and MG2_177.

