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Dietary habits in medieval and early modern Estonia: evidence from stable isotope analysis

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ABSTRACT

New stable carbon and nitrogen isotopic analyses from medieval and early modern sites across Estonia demonstrate systematic differences in the dietary habits of people from various locations and social groups. These results are compared with previously published isotopic data from similar contexts to identify the type and origin of dietary items, specifically in terms of aquatic resource consumption. Distinction between protein sources is, however, complicated by the high degree of isotopic variation among aquatic ecosystems and the fact that resources from multiple habitats were routinely exploited, resulting in a mixing of the isotopic signal. Nitrogen isotopic ratios display variations in the consumption of higher trophic level protein (such as fish), differentiating between rural, urban and elite individuals, as well as between males and females. Carbon isotopic ratios show a clear distinction between humans from coastal and inland sites, likely reflecting the importance of Baltic Sea fish to coastal communities. However, the exact quantification of aquatic resources into the diets of historic period people in the region needs further work.

KEYWORDS

palaeodiet, stable isotopes, Medieval Period, Early Modern Period, Estonia.

Introduction

Ever since the first revolutionary applications of stable carbon and nitrogen isotope analysis of archaeological skeletal remains in the 1970s and 80s (e.g. Vogel & van der Merwe 1977; Tauber 1981; Schoeninger & DeNiro 1984; Ambrose & DeNiro 1986), this method has proven to be extremely valuable for providing new insights into a wide range of research questions. Isotope analyses are indispensable for studies concerned with the prehistoric period where the available evidence is limited by preservation issues. However, when combined with ample artefactual and osteological data, and written sources characteristic to historic periods, this quantitative method presents the opportunity to either support or disprove our existing knowledge concerning various topics from our recent past.

One such topic is the importance and consumption of marine resources in the eastern Baltic region during the Medieval and Early Modern Periods. This issue is particularly well suited for stable isotope studies, since marine resource consumption is generally well distinguishable with this method (Schoeninger & DeNiro 1984). However, published isotopic data from other northern European medieval and post-medieval populations has not indicated any significant reliance on marine foods, suggesting instead a diet predominantly terrestrial in origin, focusing mostly on domestic animal protein and cultivated plants, although with minor additions from freshwater fish (Müldner & Richards 2005, 2007a, 2007b; Kjellström et al. 2009; Linderholm & Kjellström 2011; Simčenka et al. 2020; Skipitytė et al. 2020). This seems to contradict other lines of evidence, which have demonstrated extensive trade of North Sea fish to the Baltic ports (Barrett et al. 2008, 2011; Orton et al. 2011) as well as the widespread availability of marine fish to all social classes (Põltsam-Jürjo 2013, 2018).

To further explore this problem, new stable carbon and nitrogen isotopic analyses were conducted for 126 humans sampled from various contexts across historic period Estonia. These results were compared with other related datasets to identify patterns in dietary consumption and potential temporal and spatial changes in the dietary habits of populations from various contexts. The human dataset was analysed in the framework of faunal baseline isotope data to identify the type and origin of dietary items, specifically in terms of aquatic resource consumption. The results enable us to explore the nature and direction of local foodways, and to determine the importance of imported fish for human diets.

Material

Altogether 126 samples were collected from 15 sites (Fig. 1), summarised in Table 1. Some sites are represented by only a few individuals. This was due to the small collection size of available material, which in some regions and contexts has been affected by poor preservation and limited excavation history. However, these sites were still included to obtain a representation of different contexts, periods and regions across the study area. The current study is not focused on looking at individual dietary patterns but rather explores the wider trends that can be used to characterise larger groups of people.

To follow patterns at the population level, sites are further divided into discrete categories. The location and the surrounding environment have a great effect on the availability of food resources, and ever since the prehistoric times, there has been a stark divide between resource utilisation in coastal vs inland areas (Tõrv 2018). For our study, all sites were categorised as either ‘coastal’ (broadly corresponding to sites in northern and western Estonia) or ‘inland’ (sites in southern Estonia).

TABLE 1. Overview of human samples chosen for this study along with the number of samples and contextual information. The site numbers (No.) correspond to the locations on the map in Fig. 1

No.	Site name	Location	Region	Assigned period	Date	Context	N
1	St Catherine's Church	Tallinn	Coastal	Medieval	13th–15th c.	Elite	2
	Church of the Dominican Friary in Tallinn. Individuals buried inside the church were considered a part of the societal elite, either secular or clerical.						
2	St John's Leprosarium	Tallinn	Coastal	Early Modern	15th–17th c.	Urban	8
	Cemetery of the medieval almshouse/leprosarium outside the city walls of Tallinn, which in later periods was also used to bury regular citizens.						
3	Niguliste St cemetery	Tallinn	Coastal	Medieval	11th–12th c.	Rural	4
	Two graves (including a triple burial) that likely represent the remains of a pre-Christian settlement in the area where Tallinn Old Town was later established.						
4	Pärnu Rd cemetery	Tallinn	Coastal	Early Modern	18th c.	Urban	1
	1710 plague cemetery, possibly a soldier of the Russian Empire from the Northern War.						
5	Leppneeme cemetery	Leppneeme	Coastal	Early Modern	17th–18th c.	Rural	2
	Local burial place for a fishing village outside Tallinn.						
6	Valjala churchyard	Valjala	Coastal	Medieval	13th–14th c.	Rural	23
	Rural churchyard on the island of Saaremaa, established during the initial Christianisation of the region in the 13th century.						
7	Lihula cemetery	Lihula	Coastal	Early Modern	17th–18th c.	Rural	3
	Context unclear but was included to obtain a representation for the western mainland coastal region.						
8	St Michael's churchyard	Rakvere	Coastal	Medieval/Early Modern	13th–17th c.	Urban	19
	Urban churchyard with a long burial history. Rakvere was a minor town, located about 20 km from the northern coastline.						
9	Pikk St execution site	Rakvere	Coastal	Medieval	13th–15th c.	Urban	3
	Possible site for burying execution victims, found near St Michael's Church in Rakvere. All three individuals had signs of decapitation on their skeleton.						
10	Lossi St mass grave	Tartu	Inland	Early Modern	16th–17th c.	Urban	12
	Mass grave, possibly related to an epidemic outbreak or famine.						
11	Pikk St cemetery	Viljandi	Inland	Medieval/Early Modern	13th–18th c.	Urban	6
	Urban cemetery that was in use for a short period of time as evidenced by low burial density.						
12	St Mary's churchyard	Põlva	Inland	Early Modern	18th c.	Rural	3
	Triple burial, possibly related to an episode of famine or epidemic.						
13	Piiri St cemetery	Otepää	Inland	Medieval	14th c.	Rural	14
	Cemetery for burying plague victims.						
14	Vastseliina cemetery	Vastseliina	Inland	Early Modern	16th–18th c.	Rural	10
	Borough cemetery of Vastseliina, contained both single graves and a mass grave.						
15	Siksali (Siksälä) cemetery	Siksali	Inland	Medieval	13th–15th c.	Rural	16
	Rural cemetery at the southeastern edge of Estonia with influences from the eastern (Novgorod) and southern (Latvian) cultural spaces, some burials covered in mounds.						

FIG. 1. Location map of Estonia and sites included in the study.
The numbers correspond to the sites in Table 1.

Rural sites include both village cemeteries and borough cemeteries, and likely reflected predominantly the low social class ethnic Estonians, whereas urban sites are from larger towns, which are characterised by diverse social levels and ethnicities, intensive trade activities, and active movement of people and goods (Kala et al. 2012).

Some of the burial sites were in use over several centuries, which is why assigning ages to the sites (or even for individual inhumations) was complicated. For this reason, broad temporal categories were used with partly overlapping groups. While this means that temporal continuity cannot be directly followed and may obscure short-term dietary variations, a broad comparison between the earlier period ('medieval', from ca 12th–15th century, including burials from the final phase of the Iron Age) and later period ('early modern', ca 16th–18th century) was attempted, with an in-between group of 'medieval/early modern' used for sites that may have been in use during either or both of the periods. The site on Niguliste Street in Tallinn is here assigned to the 'medieval' group, although chronologically it likely predates the official Christianisation of the region and represents the local (ethnic Estonian) population. For this reason, it is also the only site from Tallinn that is categorised as 'rural' instead of 'urban'.

The new isotope data will be discussed alongside already published evidence about medieval and early modern Estonian skeletal collections (see Fig. 1). These include two larger sampled populations in northern Estonia: the urban St Barbara's cemetery in Tallinn and Kaberla village cemetery in northern Estonia (Aguraiuja-Lätti & Lõugas 2019); additional samples from medieval Tallinn and Kaberla village cemetery sampled for a previous study (Lightfoot et al. 2016); and several sites from medieval and early modern Tartu and the nearby Lohkva village cemetery in southern Estonia (Malve et al. 2023; only adult individuals). Information about sample selection, context and methodology is available from the respective publications of each study.

Methodology

Stable isotope analysis is based on the premise 'you are what you eat', where the isotopic composition of body tissues (such as bone collagen) reflects the average isotopic composition of consumed foods (especially the protein portion of diet) over the last several years before death (Hedges et al. 2004). Carbon isotopic ratios – (δ^{13}C) – of organisms differ between marine and terrestrial ecosystems in a predictable manner, with purely marine feeders having δ^{13}C values of around –14‰ and purely terrestrial feeders around –22‰ (Schoeninger & DeNiro 1984; Schoeninger & Moore 1992; Sealy 2001). Freshwater fish can exhibit widely varying carbon isotope ratios. δ^{13}C of fish bones from the Baltic Sea region was found to range between –28‰ and –12‰, partly overlapping with those of both marine and terrestrial fauna (Grupe et al. 2009; Reitsema et al. 2013; Simčenka et al. 2020; Aguraiuja-Lätti et al. 2022).

Nitrogen isotopic ratios – δ^{15}N – increase by about 4‰ with every trophic level, with plants having low δ^{15}N values (around 0–2‰), followed by herbivores, omnivores and top predators (Bocherens & Drucker 2003; Hedges & Reynard 2007). Since aquatic ecosystems have longer food chains, some aquatic species tend to have higher δ^{15}N values (over +12‰) compared to terrestrial fauna (Schoeninger & DeNiro 1984).

Isotopic ratios were measured from bone collagen, extracted from samples taken from the rib, when possible. Other skeletal elements were used when ribs were not available. Adult individuals were preferred whenever the size of the collection allowed it, but in some cases also subadult individuals were included to obtain a better representation of the local human isotopic signal. None of the subadult samples were from infants who may have been breastfed and whose isotopic ratios may have been thus affected by the nursing effect (Fuller et al. 2006). Samples were prepared in Tallinn University, Estonia, and collagen was analysed for stable isotope ratios in the Scottish Universities Environmental Research Centre (SUERC), United Kingdom. Approximately 20% of the samples were run in duplicate and the average 1-sigma standard deviation of the duplicates was ±0.04‰ for δ^{13}C and ±0.03‰ for δ^{15}N. Sample preparation and analysis followed the methodology outlined in Aguraiuja-Lätti & Lõugas (2019).

Results

123 samples out of 126 produced enough collagen for analysis. All samples had quality criteria within the accepted limits for well-preserved collagen (DeNiro 1985;

Ambrose 1990; van Klinken 1999). Results are shown in Fig. 2, with a full list of results along with quality indicators and contextual information for each sample found online (Aguraiuja-Lätti 2023). All individuals have $\delta^{13}C$ values between –21.7‰ and –18.5‰ (average –20.3‰ ± 0.7‰) and $\delta^{15}N$ values between +8.2‰ and +14.1‰ (average +10.5‰ ± 1.1‰). The $\delta^{13}C$ values display a moderate range of variation, indicating a predominantly terrestrial, C_3-plant based diet with a minor marine resource component, which has resulted in higher values for some humans. The $\delta^{15}N$ values show a much greater range, suggesting that people were consuming protein from different sources and trophic levels.

Two individuals are outliers, with a combination of relatively high $\delta^{15}N$ and low $\delta^{13}C$ values. The young male from Pärnu Road in Tallinn was, based on the burial inventory, probably a soldier of the Russian Empire, who may have died during the 1710 plague outbreak (Malve & Tvauri 2022). The other outlier (an adult female) was buried at a mass grave in Tartu city centre (Vilumets & Malve 2020), originating from a tumultuous period in the early 18th century characterised by wars and epidemics, and may have also been a recent arrival from elsewhere in the Russian Empire, of which Estonia was a part of during that time. Their distinct isotope ratios may reflect different dietary habits and/or differences in baseline isotopic values between Estonia and their native land.

There is a clear divide between coastal sites (average $\delta^{13}C$ and $\delta^{15}N$ values of –19.6‰ and +11.1‰, respectively) and inland sites (average values –20.6‰ and +10.2‰, respectively), with the former having statistically significantly higher $\delta^{13}C$ and $\delta^{15}N$ values (Mann-Whitney U test, $U = 110$, $p < 0.001$ for $\delta^{13}C$; and $U = 1280.5$, $p = 0.002$ for $\delta^{15}N$). The coastal-inland distinction in isotopic values seems to be independent of whether the site is urban or rural (there are no statistical differences

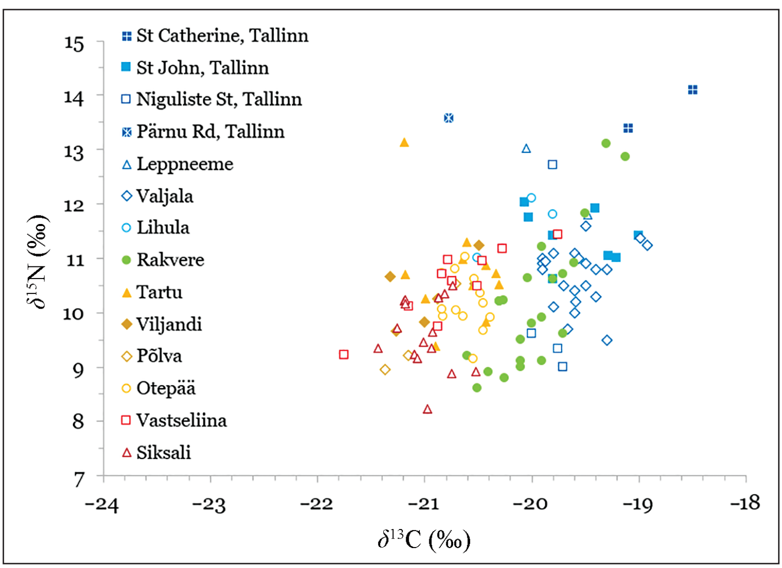

FIG. 2. Scatterplot of new $\delta^{13}C$ and $\delta^{15}N$ measurements of historic populations across Estonia. Open symbols are rural sites, closed symbols – urban sites.

between urban and rural sites, as $p > 0.265$ for both variables), although urban sites do have on average slightly higher $\delta^{13}C$ and $\delta^{15}N$ values.

A unique case was presented by the site of Rakvere, which demonstrated an overlap with both regions (see Fig. 2). Although categorised as a 'coastal' site, it is situated further from the coast (ca 20 km) than others in this group. When individuals from Rakvere are looked at separately, they have statistically similar $\delta^{13}C$ values but different $\delta^{15}N$ values compared to individuals from other coastal sites, and vice versa when compared with inland individuals. Although the differences between coastal and inland sites remain statistically significant regardless of which group includes Rakvere (Mann-Whitney U test, $p < 0.001$ for both comparisons, $U = 291$ for $\delta^{13}C$, $U = 799$ for $\delta^{15}N$, if Rakvere is included among inland sites), because of the closer proximity to the sea and the greater overlap of Rakvere isotope values with those from coastal sites, we will continue to consider it as a coastal site in the following discussion.

Our dataset suggests, unsurprisingly, that there was a stronger preference for marine resources in coastal populations. This is supported by the existence of a statistically significant positive correlation between $\delta^{13}C$ and $\delta^{15}N$ values (Pearson's $r = 0.445$, $p < 0.001$). If the two outliers mentioned above are removed, the correlation is even stronger ($r = 0.531$, $p < 0.001$). The fact that higher $\delta^{13}C$ values are associated with higher $\delta^{15}N$ values indeed suggests that marine resource consumption of varying degrees has affected the dataset, since marine resources have higher $\delta^{13}C$ and $\delta^{15}N$ values compared to terrestrial resources.

Individuals with both the highest and the lowest $\delta^{13}C$ and $\delta^{15}N$ values represent the end-members on a scale of increasing reliance on higher trophic level (including aquatic) protein. The highest $\delta^{13}C$ and $\delta^{15}N$ values from St Catherine's Church in Tallinn are associated with a monastery; monastic diet in the Baltic region was known to rely heavily on fish as a dietary source (Simčenka et al. 2020; Lõugas & Bläuer 2021). On the other hand, the lowest values are from rural settlements in southern Estonia, where diet seems to have been overwhelmingly based on terrestrial resources. Most of these rural inland sites are located far away from both large bodies of water and major trading centres and towns, which further reduced the availability of aquatic resources for consumption.

Discussion

LOCAL DIETARY TRENDS IN COASTAL AND INLAND REGIONS

The results presented here demonstrate the importance of large datasets for detecting unique trends in local consumption patterns. This becomes especially clear when these new data are combined with previously published isotopic information from various medieval and early modern contexts in Estonia (Fig. 3; stable isotope data summarised in Aguraiuja-Lätti 2023). Comparative data broadly follow the same trends as seen in Fig. 2, confirming the existence of systematic differences in access to certain foodstuffs between coastal and inland regions. Statistical analyses

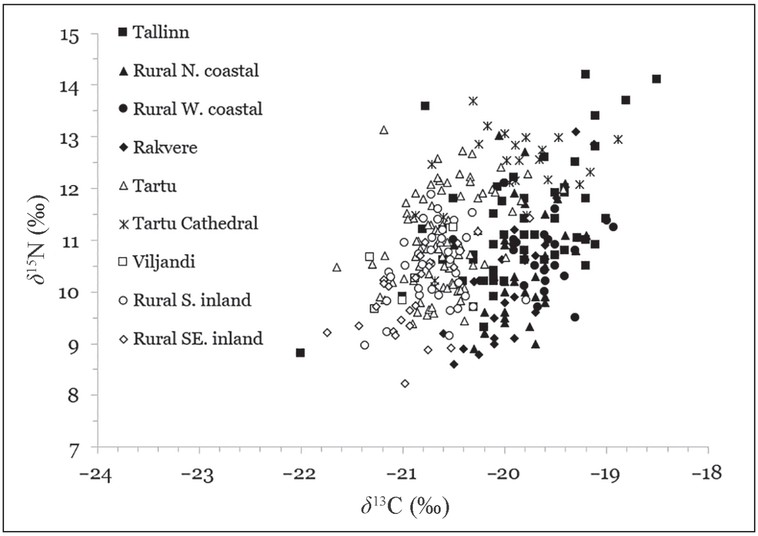

FIG. 3. Scatterplot of new δ^{13}C and δ^{15}N measurements from this study combined with published data from Lightfoot et al. (2016), Aguraiuja-Lätti & Lõugas (2019) and Malve et al. (2023; only adult individuals). Data from smaller rural sites are grouped by broader regions (northern coastal, western coastal, southern inland, southeastern inland). Open symbols are inland sites, closed symbols – coastal sites; Tartu Cathedral is shown separately.

confirm that coastal sites (average δ^{13}C and δ^{15}N values of –19.8‰ and +10.8‰, respectively) are significantly different from inland sites (average values –20.6‰ and +11.0‰, respectively) when compared for their carbon isotope ratios (Mann-Whitney U test, $U = 3205.5$, $p < 0.001$), but not for nitrogen ($U = 14520.5$, $p = 0.166$). This similarity of δ^{15}N values across regions has been affected by the inclusion of elite individuals from inland Tartu (Malve et al. 2023), who have noticeably different isotope values compared to other inland populations (see also Fig. 4).

In the extended dataset, there is a more visible overlap between coastal and inland sites, at least some of which can reasonably be explained by local migration, i.e. people moving from their birthplace to another location shortly before their death. The two big urban centres of Tallinn and Tartu both display a wide range of stable isotope values, which is in agreement with historic towns surviving on an influx of immigration from other places, but is also influenced by different social classes with access to a wider selection of dietary resources characteristic to urban life in these periods (Põltsam-Jürjo 2013).

Access to dietary resources was certainly dictated by an individual's social status. Rural peasants could be considered to represent the lowest social class, whose dietary choices were entirely dependent on natural resources and climatic conditions, e.g. success of crop harvests (Põltsam-Jürjo 2013). Urban dwellers comprised people of various backgrounds, from peasants who had come to towns in search of work to merchants and craftsmen with better access to a wider range of goods. The highest social ranks were filled by foreigners, mostly ethnic Germans, who made up the clerical and secular elite, e.g. bishops, monks and lords.

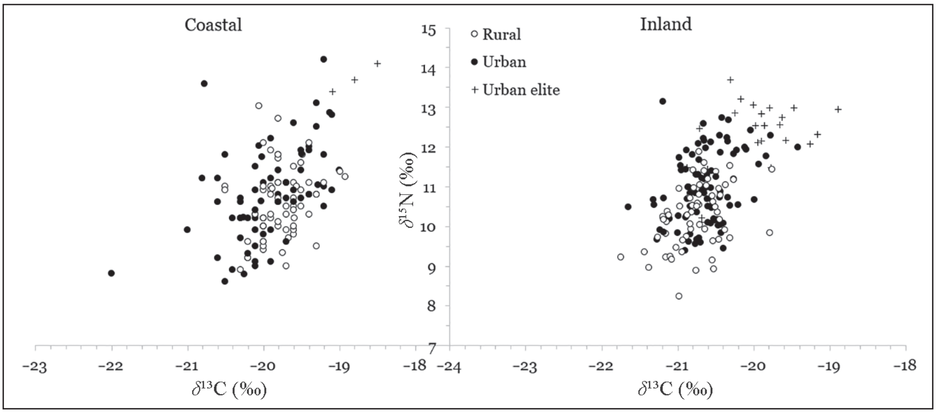

FIG. 4. Scatterplot of δ^{13}C and δ^{15}N measurements of medieval and early modern Estonian coastal and inland populations by context and social status.

In Fig. 4, coastal and inland sites associated with either rural, urban or elite burial contexts are compared. The two regions show slightly different trends. Among coastal sites, urban and rural commoners are statistically significantly different in their δ^{13}C values (Mann-Whitney U test, $p = 0.032$, $U = 2680$) but not in δ^{15}N values ($p = 0.203$, $U = 1922.5$). Urban commoners have on average the lowest δ^{13}C values, whereas their rural counterparts have the lowest δ^{15}N values. It is somewhat surprising that rural coastal populations have higher δ^{13}C values (indicating consumption of ^{13}C enriched foods, such as marine resources) compared to coastal urban dwellers, but this may be influenced by the inclusion of migrants from inland regions into coastal towns. This is also indicated in Fig. 3, where several individuals from coastal sites have δ^{13}C values more similar to those of inland inhabitants. When looking at inland sites separately, rural and urban sites show small yet significant differences for both carbon and nitrogen values (Mann-Whitney U test, $p < 0.008$ for both), with townspeople showing higher values for both proxies. A similar result was reported in a study concerning non-adult individuals from medieval and early modern urban and rural contexts in southern Estonia (Morrone et al. 2023).

Although urban and rural commoners show a significant overlap in their isotopic values, the evidence does suggest that there were clear differences between the two groups in terms of consumption of dietary items enriched in ^{13}C and ^{15}N. The most likely cause of this is the greater reliance on higher trophic level protein (including fish) in urban regions. Many coastal rural populations also displayed high carbon and nitrogen isotopic values – this is likely due to coastal regions having better access to aquatic resources, e.g. through coastal fishing activities, which would have provided an affordable and accessible dietary resource even to rural peasants.

The (urban) elite is well distinguished from other social classes, with elite burials from inland Tartu Cathedral occupying a similar part of the graph as coastal elite burials from St Catherine's Church in Tallinn (Fig. 4). For both regions, elite burials display some of the highest δ^{13}C and δ^{15}N values, up to –18.5‰ and 14.1‰, respectively. Values in this range are not characteristic of diets based on terrestrial resources, and signify a considerable marine component in diet. This is in accordance with the societal elite (which included clergy) being more likely to rigidly follow fasting rules, which emphasises the importance of fish as a fasting food (Adamson 2004). Considering that several individuals from non-elite burial locations had similar isotopic values, they can be cautiously interpreted as people of above-average social rank. These include several individuals from St Barbara's cemetery in Tallinn, St Michael's churchyard in Rakvere, and St Mary's churchyard in Tartu. The latter two especially were regionally important churches where urban dwellers of various backgrounds were likely interred (Alttoa 2009; Malve et al. 2020).

Despite their similarities, the elite burials from the two regions do not show any overlap in their isotopic values, with those from Tallinn being higher for both carbon and nitrogen. This can be due to the small sample set from the coastal region, which may not be representative of the general elite of Tallinn. In addition, St Catherine's burials may reflect the clerical elite, since it was associated with a monastery (Lightfoot et al. 2016), whereas Tartu Cathedral may have represented the secular elite, since also laymen and various lords and benefactors were buried there (Malve et al. 2023). However, the results of Tartu Cathedral are very similar to those of early modern monks from Vilnius (Lithuania), who would have also likely consumed a high social class diet with a strong emphasis on fish (Simčenka et al. 2020). But the most probable explanation for the distinction between the two elite datasets lies in better access to marine resources for St Catherine's Church, whereas individuals buried at Tartu Cathedral likely relied more on freshwater fish, which tend to have more negative δ^{13}C values.

Figure 5 shows coastal and inland populations plotted based on the assigned chronological period of the burial location. For coastal regions, δ^{13}C values are similar for all periods but δ^{15}N values of early modern individuals are statistically significantly higher compared to other periods (Kruskal-Wallis H test, $p < 0.001$). For inland sites, no statistical differences were found between periods for either δ^{13}C or δ^{15}N; however, this perceived similarity has been influenced by medieval

FIG. 5. Scatterplot of δ^{13}C and δ^{15}N measurements of medieval and early modern Estonian coastal and inland populations by period.

burials from Tartu Cathedral, which have high $\delta^{15}N$ (similar to some other early modern individuals). Indeed, Malve et al. (2023) reported that when cathedral burials were excluded from the comparison, then early modern inhabitants of Tartu had higher mean $\delta^{13}C$ and $\delta^{15}N$ values compared to medieval commoners. The same trend is visible in the current analysis when removing the cathedral dataset, where early modern burials have on average significantly higher values compared to other periods (Kruskal-Wallis H test, $p < 0.012$ for both proxies), although the shift in mean values is small (around 0.2‰ for $\delta^{13}C$ and 0.5‰ for $\delta^{15}N$).

This small yet statistically significant shift in values (especially for $\delta^{15}N$) suggests that there was a change in either the type or amount of certain dietary resources between the Medieval and the Early Modern Periods. Since more individuals from the Early Modern Period had higher $\delta^{13}C$ and $\delta^{15}N$ values, this suggests that there was an increased reliance on higher trophic level protein in later periods. However, it is difficult to elaborate on these dietary changes due to a noticeable overlap in earlier and later period values, and the uncertainty surrounding the direct dating of the analysed skeletal remains. Any temporal patterns may also be skewed by other factors that have affected dietary habits, such as distance from the coast (e.g. inlanders with lower $\delta^{13}C$ values who relocated to coastal regions before death) or individual differences in access to food items (e.g. the case of the triple grave from Niguliste Street in Tallinn, where a male and a female buried together have values that vary by a full trophic level).

To better assess the effect of individual differences in access to dietary resources, Fig. 6 compares males and females from coastal and inland areas. The highest $\delta^{13}C$ and $\delta^{15}N$ values belong to males, whereas the lowest results are seen in females, and this is also reflected in their mean values. However, the differences between males and females may have been influenced by their social status, since most elite individuals (who also have distinct values) were males. Excluding elite burials, the differences between male and female diets are statistically significant only at the inland sites (Mann-Whitney U test, $p < 0.017$ for both proxies).

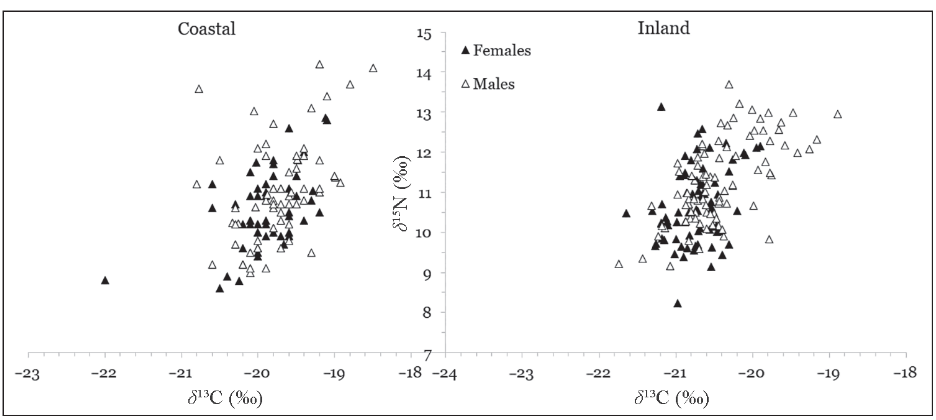

FIG. 6. Scatterplot of $\delta^{13}C$ and $\delta^{15}N$ measurements of medieval and early modern Estonian coastal and inland populations by sex.

Male-female differences are mostly manifested in δ^{15}N values, with males from coastal and inland areas having nearly identical mean values (+10.9‰ and +10.9‰, respectively), and the same applies for females (+10.5‰ and +10.6‰, respectively). On the other hand, δ^{13}C values are much more similar between males and females from the same region compared to, for example, males from different regions (coastal males: –19.8‰; coastal females: –19.9‰; inland males: –20.6‰; inland females: –20.8‰). This indicates that males in general consumed higher trophic level (animal and aquatic) protein compared to females, but the type of consumed protein differed between coastal and inland regions for both sexes. Other studies on comparable populations have also demonstrated lower values for women compared to their male counterparts (from the same social strata) and have suggested lifestyle differences as one of the probable causes for this (see Malve et al. 2023 and references therein). In medieval Estonia, animal meat in particular was considered as a source of masculinity and power, with women consuming less meat (both in quantity and in frequency) compared to men (Põltsam-Jürjo, this issue).

ISOTOPIC AND ARCHAEOLOGICAL EVIDENCE FOR DIETARY HABITS IN MEDIEVAL AND EARLY MODERN ESTONIA

One of the most substantial dietary changes that occurred in the Baltic region starting with the Medieval Period was the rising importance of (marine) fish consumption as attested by both historical and zooarchaeological evidence (Põltsam-Jürjo 2013, 2018; Lõugas & Aguraiuja-Lätti, this issue). This was influenced by Catholic traditions that prohibited the consumption of meat during fast days but was likely also spurred by increased population growth across Europe (Adamson 2004). Next to bread and meat, fish was an important dietary staple and an affordable source of protein in the absence of meat (Põltsam-Jürjo 2013, 2018). Although various species of both marine and freshwater fish were consumed, their relative contribution to human diets has thus far been difficult to quantify.

To provide a more detailed reconstruction of diet, in Fig. 7 the assembled dataset of historic period human isotopic data from Estonia is plotted against the reference values of local terrestrial and aquatic fauna from related contexts (Aguraiuja-Lätti et al. 2022). The isotopic data of terrestrial animals demonstrate the expected isotopic niche positions of wild terrestrial mammals (consuming wild plants), domestic herbivores (consuming both wild and cultivated plants) and domestic omnivores (consuming a combination of plant and animal protein). In regard to these reference data, humans show a noticeable overlap in their isotopic values with (some) domestic omnivores (including dogs, pigs and chickens), suggesting a similar dietary intake focusing on cultivated plants (grains and vegetables) and terrestrial animal protein (meat, dairy and eggs).

A fine example of an almost entirely terrestrial diet is seen for Bronze Age individuals from Jõelähtme grave complex in northern Estonia (Laneman 2021), with those from Iron Age Kukruse cemetery (Oras et al. 2018) also having similar average carbon and nitrogen isotope ratios (Fig. 7). Values in this range are also

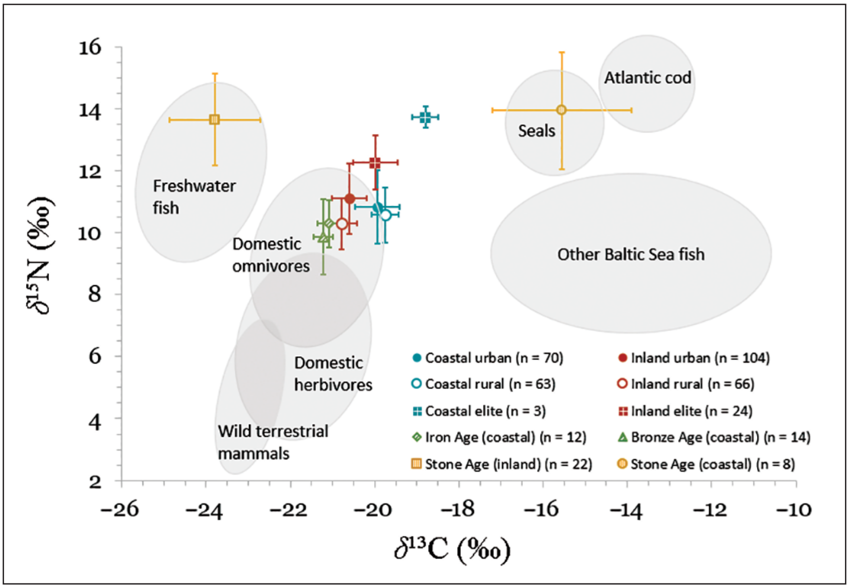

FIG. 7. Medieval and early modern δ^{13}C and δ^{15}N data compared to earlier period sites across Estonia. Human data are from this study and Lightfoot et al. (2016), Aguraiuja-Lätti & Lõugas (2019), Malve et al. (2023). Additional human data are from the Bronze Age (Jõelähtme; Laneman 2021), the Iron Age (Kukruse; Oras et al. 2018) and the Stone Age (Kivisaare-Tamula-Veibri, Kõljala-Kõnnu-Naakamäe; Tõrv 2018). Mean values and the 1-sigma standard deviation range are shown with error bars for human populations. Shaded circles represent the approximate range of faunal values, after Aguraiuja-Lätti et al. (2022). 'Other Baltic Sea fish' include both marine and freshwater species living in brackish conditions.

seen for Latvian Bronze Age populations (Oinonen et al. 2013; Vasks et al. 2021). These results are entirely comparable to those from the medieval cemetery at Siksali, which is one of the furthest sites from the coast amongst our study material; a remote village in the southeastern corner of Estonia, where the old Iron Age traditions persevered longer than in other parts of the land (Valk & Laul 2014).

When looking at rural inland sites as a whole, however, we observe a slight shift towards higher δ^{13}C and δ^{15}N values compared to earlier periods (Fig. 7), and coastal and inland rural populations have generally overlapping δ^{15}N values (on average +10.3‰ vs +10.6‰, respectively; see also Fig. 4), suggesting that they consumed protein from similar trophic levels. We have no reason to believe that rural medieval populations would have abstained completely from fish, rather it seems likely that fish was not an important part of the village diet. Compared to rural individuals, most urban and elite sites show much higher δ^{15}N values, which indicates that they either consumed proportionally more protein or protein with higher nitrogen isotopic values. While elite diet could certainly be characterised as protein-heavy (see e.g. Malve et al. 2014), the latter option seems more probable when discussing commoners from urban contexts.

Consumption of omnivores (such as pigs) and intensively manured plants (either directly or indirectly through livestock foddered on manured plants) can both result in elevated human δ^{15}N values (Müldner & Richards 2007b; Bogaard et al. 2013; Hammond & O'Connor 2013; Szpak 2014). Although the range of isotopic values for domestic herbivores from Estonia do not indicate that they consumed heavily manured plants (Aguraiuja-Lätti et al. 2022), there is some evidence that manuring and intensive agriculture was practised in the region already at the end of the Iron Age (Sammler 2021). Pigs from historic period contexts do have relatively high δ^{15}N values (on average +8.3‰), which could account for the observed high human nitrogen isotope ratios. Unlike other domesticates, pigs were only kept for meat, and their consumption could have thus had a proportionally greater effect on human δ^{15} values. However, neither manuring nor consumption of omnivore protein would result in a significant increase in carbon isotopic ratios. Yet in our dataset there is a clear trend of higher δ^{13}C values being accompanied with higher δ^{15}N values, which is typically interpreted as the influence of marine resource consumption.

Pure marine feeders, such as Meso-Neolithic seal hunters of Saaremaa island (Tõrv 2018), have isotopic values that are very similar to seals and are approximately one trophic level higher compared to Baltic Sea fish (Fig. 7). Although it is clear that historic period populations did not consume marine resources on a comparable level, this indicates how consumption of (marine) fish would result in very high δ^{13}C and δ^{15}N values. The group most similar to Stone Age coastal populations in their isotopic values are the presumed monks from St Catherine's Church in Tallinn. They have comparable δ^{15}N values, but much lower δ^{13}C values. This confirms that individuals from St Catherine's consumed a diet heavily reliant on (high trophic level) aquatic resources, which likely also included freshwater species with more negative δ^{13}C values. These high-status individuals could have also consumed imported marine resources (such as cod from the North Sea and the Atlantic Ocean), which have some of the highest δ^{13}C and δ^{15}N values analysed from Estonian zooarchaeological material (Orton et al. 2011, 2019; Aguraiuja-Lätti et al. 2022).

Isotopic and zooarchaeological evidence attests to the fact that the Atlantic cod was present in urban areas (including Tallinn, Tartu and Pärnu) and in the castles of the elite (including Otepää, Viljandi and Uue-Kastre) (Orton et al. 2011, 2019; Aguraiuja-Lätti et al. 2022), but its consumption is not reflected in the current human isotopic dataset. Cod with stable isotope values consistent with an Atlantic origin is almost exclusively very large in size, and as such it was probably relatively expensive and thus predominantly consumed by the upper social classes. On the other hand, the popular and much more affordable (and smaller) herring would have been a regular component of the commoners' menu, and was often imported from the western Baltic Sea and the Kattegat/Skagerrak region (Põltsam-Jürjo 2013; Atmore et al. 2022). Although we do not have any relevant isotopic data from Estonia, medieval herring from Swedish sites has average δ^{13}C and δ^{15}N values of around –14‰ and +11‰, respectively (Arcini et al. 2012), similar to some other Baltic Sea fish (Fig. 7).

This underlines one of the main problems of reconstructing aquatic resource exploitation in historic period northern Europe – due to the brackish conditions of the Baltic Sea, local marine fauna has been shown to have much more varied carbon isotopic ratios compared to the Atlantic (Craig et al. 2006; Eriksson et al. 2008; Orton et al. 2011), fluctuating in correlation with salinity levels (Emeis et al. 2003). Likewise, Baltic Sea fish tend to be smaller than their oceanic counterparts, resulting in lower δ^{15}N values (Aguraiuja-Lätti et al. 2022). Because of this, detecting low or moderate consumption of marine resources is difficult in this environment. Consequently, many studies on northern European medieval and early modern populations that have reported similar results of terrestrial-looking carbon and elevated nitrogen isotopic ratios (e.g. Müldner & Richards 2005; Linderholm & Kjellström 2011; Petersone-Gordina et al. 2018; Simčenka et al. 2020; Skipitytė et al. 2020) may have underestimated the importance of (Baltic Sea) marine resources.

These previous studies have generally explained the observed human isotopic signal as influenced by the consumption of freshwater fish, which tend to have widely variable δ^{13}C values partly overlapping with the terrestrial range. Even analysed freshwater species from Estonia (with δ^{13}C values anywhere between –26‰ and –11‰) average around –19‰ (Aguraiuja-Lätti et al. 2022), so this interpretation would be entirely feasible. But it must be cautioned that similar human isotopic values do not always indicate similar diets, and conversely, two individuals consuming the same dietary resources may have very different isotopic ratios if their food originates from habitats with different baseline values. Our dataset could thus be explained either by a very minimal consumption of aquatic resources and a high consumption of terrestrial animals, or a much more significant consumption of fish from various habitats with different (carbon) isotopic values.

The first interpretation seems unlikely considering the available historical and zooarchaeological evidence. It is certainly possible that written accounts concerning fish trade and consumption are not entirely representative or accurate, that the specific amount consumed by a single individual was actually very small, and that ethnic Estonians might not have rigidly followed fasting guidelines. But it is doubtful that the local communities would not have exploited the easily available and affordable protein source that was fish, consumption of which was sanctioned by the ruling class. Thus, the more probable explanation would be that aquatic resources were indeed a substantial part of medieval and early modern diet, and this would be in accordance with the available isotopic evidence.

The reported divide between δ^{13}C values of coastal and inland populations is most probably caused by a greater reliance on Baltic Sea resources (both marine and brackish) in coastal regions. This is supported by other studies in this issue, e.g. concerning the zooarchaeological analyses of aquatic fauna (Lõugas & Aguraiuja-Lätti, this issue) and the dietary habits of dogs (Nuut et al., this issue), which demonstrate the same preference for marine resources in coastal sites and freshwater resources in inland sites. However, it is also possible that people (from similar social groups) living in both inland and coastal areas may have actually consumed the same menu with the same aquatic species, but $\delta^{13}C$ differences between freshwater fish living in inland freshwater vs coastal brackish waters would in itself be enough to cause the observed differences in the human isotopic record. Similarly, individual differences in isotopic values most likely reflect the relative proportion of consumed fish (i.e. some consuming more than others), but can also be caused by isotopic differences that stemmed from the specific catch regions of the consumed fish (e.g. elite individuals consuming the more expensive Atlantic cod).

Conclusions

The analysis of the newly presented and previously published stable isotope data of humans from medieval and early modern contexts in Estonia has demonstrated that there existed systematic differences in access to higher trophic level (including aquatic) protein. The human isotopic dataset can be characterised by high levels of individual variation, which has been affected by a multitude of factors, including social status, location (urban vs rural), distance from coast, and sex-based differences in access to protein sources. There is a clear distinction between coastal and inland resource utilisation reflected in human carbon isotopic ratios, best explained by an increased reliance on Baltic Sea fauna for coastal populations and likely also a proportionally greater reliance on freshwater resources in inland regions. The results suggest that most (non-elite) people consumed locally sourced foods and aquatic resources that were most conveniently available to them. Imported marine products from the Atlantic probably played only a minor role in the diets of common people, being arguably more important to the upper social class.

Considering the complex hydrological setting of the Baltic Sea, carbon isotopic ratios are not a very useful proxy to detect aquatic resource consumption in this region. On the other hand, nitrogen isotopic ratios seem to be a more trustworthy indicator, with human $\delta^{15}N$ values of over 12‰ suggesting considerable reliance on fish. The mixing of dietary resources from different habitats, facilitated by both Hanseatic and domestic trade, has resulted in a complicated interpretation of the human isotopic record, since food with very different isotopic signals was routinely consumed. A way forward from this impasse is through the application of additional dietary proxies, such as sulphur isotope analysis (but also carbonate or enamel $\delta^{13}C$, and compound-specific $\delta^{13}C$ and $\delta^{15}N$ analyses of single amino acids), and the quantification of consumer diets, using a statistical Bayesian mixing model (Aguraiuja-Lätti et al., in prep.) to provide a more accurate reconstruction of the complex foodways in the eastern Baltic region.

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Toitumisharjumused kesk- ja varauusaegses Eestis stabiilsete isotoopide analüüsi põhjal

Ülle Aguraiuja-Lätti ja Martin Malve

RESÜMEE

Stabiilsete isotoopide analüüs on kvantitatiivne meetod toitumise rekonstrueerimiseks, mis peegeldab elu jooksul tarbitud toidu keemilist koostist. Viimaste kümnendite jooksul on sellest meetodist kujunenud väärtuslik tööriist, uurimaks erinevaid minevikku puudutavaid küsimusi. Artikli eesmärk on vaadelda kesk- ja varauusajal Eesti alal elanud inimeste toitumisharjumusi luu kollageenist tehtud süsiniku ja lämmastiku stabiilsete isotoopide analüüsi abil. Samuti on vaatluse all

importtoidu ja eriti just imporditud meresaaduste tarbimine vaadeldud perioodil. Selleks analüüsiti 126 inimluustikku erinevatest kontekstidest üle Eesti (15 matusekohta, sh kalmistud, kirikud, kirikaiad, massihauad) ning tulemusi võrreldi sarnaste eelnevalt publitseeritud andmekogudega. Taoline suuremahuline andmestik võimaldab uurida nii laiemaid mustreid kui ka anda aimu, kui palju erines toitumine individuaalsel tasandil (st ühe regiooni või sotsiaalse rühma piires).

Tulemused osutavad, et indiviidi tasandil varieerusid toiduvalikud suuresti, olles mõjutatud erinevatest faktoritest, nagu sotsiaalne staatus, sugu ning asukoht (linn või maa). Kõrgklass, mehed ja linnaelanikud tarbisid proportsionaalselt rohkem loomseid valke võrreldes vastavalt lihtrahva, naiste ja külaelanikega. Samas tarbisid tolle aja inimesed valdavalt kohalikku päritolu toitu ning kala puhul eelistati sellist, mis oli kõige lihtsamini saadaval. Selleks oli rannikupiirkondades Läänemere vetest püütud kala ning sisemaal peamiselt jõgedest püütud kala. Samasugune muster iseloomustas kohalike toitumisharjumusi juba kiviajal, andes tõestust traditsioonide püsivusest.

Põhjamerest sisse toodud kala (peamiselt tursk) ei olnud lihtrahva menüüs eriti levinud ning oli pigem mõeldud kõrgklassi lauale. Tallinnast dominiiklaste kloostri kirikust ja Tartu toomkirikust leitud kõrgest staatusest isikute isotoopanalüüside tulemused erinesid selgelt ülejäänutest, viidates valgurikkale menüüle, kus kalal oli kindlasti tähtis roll. Samas olid Kagu-Eesti maapiirkondade maetute tulemused kõige sarnasemad pronksi- ja rauaaja eestlaste tulemustega, mil kala (eriti just merekala) tarbimine ei olnud väga levinud. Kristlike paastukommete ja kasvava rahvaarvu taustal sai kalast keskajal üks tähtsamaid toiduaineid liha ja leiva kõrval ning seda kinnitab ka käesolev uurimus. Siiski on vajalikud edasised uuringud, et täpsemalt hinnata, kui suure osa igapäeva toidust kala ikkagi moodustas ning kas ranniku ja sisemaa vahel eksisteerisid reaalsed erinevused kala tarbimises või erines vaid kalade liik.