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Human diet in Lithuania during the Late Roman and Migration periods (ca. 200–700 AD) based on stable carbon and nitrogen isotope data

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Keywords

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Abstract

In this study, 71 human individuals were subjected to stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope analysis of bone collagen samples for the purpose of determining human dietary patterns in Lithuania during the Late Roman and Migration periods. More specifically, based on the isotopic data, the aim was to determine and evaluate any potential dietary differences between individuals on the basis of their sex, age, social status and place of residence during the periods in question. The results of this study suggest that there were isotopically clearly distinguishable dietary differences between individuals from different parts/regions of Lithuania. Also, statistically significant dietary differences (on the basis of $\delta^{15}N$ values) between males and females were observed (although, when making the same sex-based isotopic comparisons at an individual site level, the same result was observed only among those from Marvelė cemetery). However, no statistically significant isotopic differences were detected between different social or age groups. Overall, these results give us one of the first glimpses into the types of dietary habits practiced by people in various parts of Lithuania during the Roman and Migration periods, which could also serve as a good starting point for future investigations into other dietary aspects in the territories and periods in question that still remain unknown.

Introduction

The Late Roman and Migration periods were a tumultuous time featuring migrations of various barbarian tribes, which were accompanied by violent military conflicts, dislocation and/or extermination of indigenous communities, which in turn led to the collapse of Western Roman Empire, as well as to changes in the social composition and cultural traditions in many parts of Europe (Halsall 2007). The territory of present-day Lithuania was also affected by various processes of this period, as attested by such archaeological finds as nomadic trilobate arrowheads embedded in human bones, along with new artefact types that were not used in previous periods (e.g. specific

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types of weapons, ornaments and other items of non-local origin made of silver or gold, etc.). New burial traditions, such as human–horse burials, an increased quantity, variety and richness of grave goods in burials, and the general concentration of the burial symbolism on warrior status suggest some form of influence from foreign barbarian cultures (Bitner-Wróblewska and Kontny 2006; Šimėnas 2006; Bliujienė and Curta 2011; Bliujienė et al. 2017; Kurila et al. 2021; unpublished data). Considering this archaeological evidence of turbulent events, it is reasonable to assume that during this time, local communities in Lithuania were significantly affected by various processes of the periods in question, which could have impacted various aspects of their lives, including their diet.

One of the aspects of human life that was most certainly affected by migratory processes of the Late Roman and Migration periods in Lithuania was the local social structure. Increased social stratification is reflected in the fact that burials in Lithuania dating to the Late Roman and Migration periods can be categorised into multiple groups according to their relative wealth (i.e. the amount of grave goods and the variety of their types per grave). The most prominent social groups distinguishable from grave goods are the elites and the commoners (with possible intermediate ranks), determined mostly by either the presence or absence of weapon sets and other markers of warrior status, as well as imports and items made of precious metals in male burials, and quantities and types of ornaments in female burials (see below for more information on the methods used to distinguish these social groups). However, this general division requires slight modification when dealing with different regions and probably with different stages of the discussed period. Furthermore, within each of these social groups, a clear difference between male and female burials is also visible, and in most cases it was possible to determine the interred individual's sex osteologically or to presume the sex according to the types of artefacts present in a grave, even in the absence of the osteological sex identification (Kurila 2009a; 2009b; Banytė-Rowell et al. 2012; Banytė-Rowell 2014).

Considering the differences in the amount and types of artefacts present in burials of individuals belonging to different sex and/or social categories, it is reasonable to assume that these perceived social differentiations among communities that lived in the territory of modern-day Lithuanian during the Late Roman and Migration periods could also have manifested in other aspects of their lives, including their daily diets. Even though some studies which explored human diets during the Migration period in such central European countries as Germany and the Czech Republic showed a clear dietary distinction between the elite and the commoner (Knipper et al. 2015) or male and female (Plecerová et al. 2020) stable isotope values, another study with similar geographical and chronological boundaries did not always detect significant differences in subsistence practices between archaeologically determined social groups and/or sexes based on the comparisons of their isotopic data (Knipper et al. 2013). Therefore, any assumptions about potential differences in subsistence practices between social groups or sexes must be confirmed or refuted by more direct evidence, such as isotopic data of the individuals in question.

Since the 1970s, stable isotope analysis has been one of the most frequently used scientific methods in human and/or animal palaeodietary studies (Lee-Thorp 2008; Katzenberg and Waters-Rist 2018). By measuring stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope ratios in human and animal bone and/or tooth collagen, it is possible to investigate such dietary aspects as relative proportions of C_3 vs. C_4 plants and/or animals that primarily subsisted on one of these two floral types (Vogel and Van der Merwe 1977; Van der Merwe and Vogel 1978), and terrestrial vs. aquatic (freshwater and/or marine) species (Chisholm et al. 1982; Schoeninger et al. 1983; Schoeninger and DeNiro 1984; Dufour et al. 1999; Katzenberg and Weber 1999; Katzenberg et al. 2011; 2012; Fuller et al. 2012), as well as other facets related to human subsistence (e.g. dietary inadequacies and pathologies, manuring practices in cultivation, infant weaning patterns etc.; Katzenberg and Lovell 1999; Bogaard et al. 2007; Fraser et al. 2011; Howcroft 2013). Since collagen is a protein, the isotopic data of analysed individuals therefore represent mainly (and in the case of $\delta^{15}N$ only) the protein fractions of all foods consumed by individuals in this study (Lee-Thorp 2008; Katzenberg and Waters-Rist 2018). Depending on which skeletal element was used for stable isotope analysis, the resulting $\delta^{13}C$ and $\delta^{15}N$ values would reflect either diet during the last 5–10 years or more of the human's life (if bone was sampled; Hedges et al. 2007; Fahy et al. 2017) or foods consumed during a particular period in childhood (if tooth was sampled; Hillson 2005).

The first, and so far the only, isotopic study which investigated human diet in Lithuania during the Late Roman and Early Migration periods was undertaken by Bliujienė et al. (2020). The results of that study suggest that the investigated humans subsisted primarily on C_3 plants and/or herbivores/omnivores that consumed these types of plants. However, in that study, the human dietary investigation only covered western Lithuania; the information on human subsistence from other parts of Lithuania is currently lacking. This study intends to address this issue by performing stable isotope analysis of individuals taken from sites located in other Lithuanian regions (eastern, central, southern), while also including new human samples from western Lithuania (Fig. 1).

Therefore, in this study we present new information on human diet in Lithuania during the Late Roman and

Migration periods based on the δ[13]C and δ[15]N values of new analysed human (n=71) bone collagen samples. To this end, both diagrammatic and statistical comparisons between isotopic data of individuals of different social statuses and both sexes were made in order to evaluate whether archaeologically perceived social differentiations and/or gender roles caused isotopically visible dietary differences in these groups. Furthermore, potential isotopic dietary differences between specific Lithuanian regions represented by different cemeteries or groups of burial sites were also explored. Finally, by using isotopic data of a large number (n=100) of faunal bone collagen samples from multiple other studies (Antanaitis-Jacobs et al. 2009; Heron et al. 2015; Piličiauskas et al. 2017a; 2017b; Bliujienė et al. 2020; Simčenka et al. 2022), a more detailed dietary baseline for prehistoric Lithuanian human populations was established.

1. Material and methods

1.1 Investigated sites

The isotopically analysed humans were sampled from skeletons that were excavated from 13 burial sites across Lithuania, representing its different regions (Table 1; Fig. 1). It was not possible to represent all regions of Lithuania equally in terms of their past human population sizes, since the number of available skeletons for stable isotope analysis was limited by the uneven number of excavated burial sites and varying bone preservation in them. Most notably, skeletal material is absent for coastal and northern Lithuania. Moreover, the practice of cremation, which started to spread in Lithuania from the second quarter of the 1st millennium AD, made it impossible to sample individuals from many cemeteries.

In eastern Lithuania, the sampled humans were buried in seven barrow cemeteries (Baliuliai, Paduobė-Šaltaliūnė III, Pavajuonis-Rėkučiai, Peršaukštis-Kasčiukai II, Santaka-Šventininkai, Sudota and Taurapilis). In this region, burial in barrows started in the Late Roman period, and from the mid-1st millennium AD, cremation became the dominant practice (Kurila 2016). Most of the sampled burials lay within a dense concentration of cemeteries, which displayed high variability in grave goods assemblages and features of intense inter-regional contact or immigration (Bliujienė and Curta 2011; Bliujienė et al. 2017).

Baliuliai is a small Late Roman – Migration period barrow cemetery. In 1999 and 2000, 12 barrows were excavated and both inhumations and cremations were found. Some

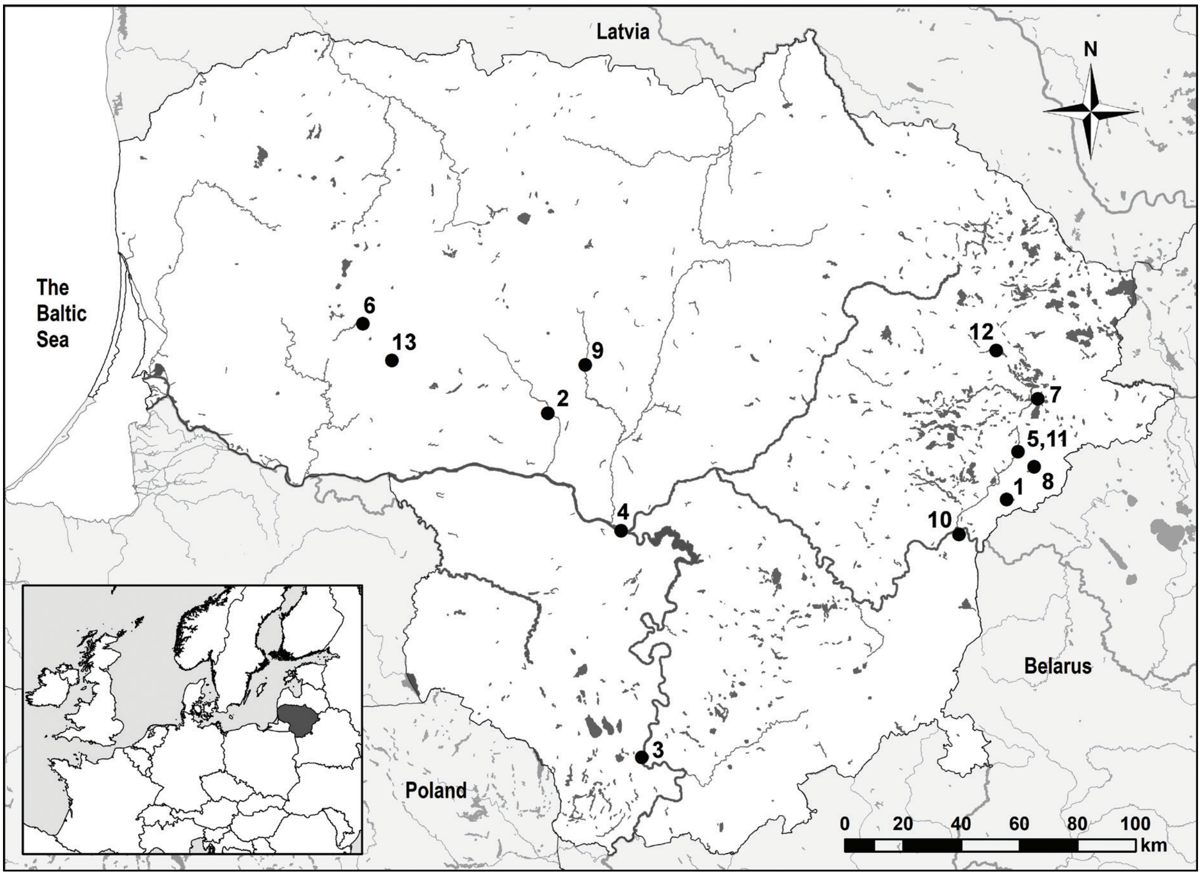

Figure 1. Map of the sites from which human bones were sampled: 1 – Baliuliai, 2 – Kalniškiai, 3 – Krikštonys, 4 – Marvelė, 5 – Paduobė-Šaltaliūnė III, 6 – Pagrybis, 7 – Pavajuonis-Rėkučiai, 8 – Peršaukštis-Kasčiukai II, 9 – Plinkaigalis, 10 – Santaka-Šventininkai, 11 – Sudota, 12 – Taurapilis, 13 – Vėluikiai (created by Kurila).

Table 1. Archaeological descriptions of each investigated burial sites and the number of analysed individuals from each Lithuanian region. site. sex. and social group.

Region	Sites	Sex	Social groups
Eastern Lithuania (n=12)*	Baliuliai (n=1)	presumed ♀ (n=1)	commoner (n=1)
	Paduobė-Šaltaliūnė III (n=1)	♂ (n=1)	chieftain (n=1)
	Pavajuonis-Rėkučiai (n=1)	♀ (n=1)	elite (n=1)
	Peršaukštis-Kasčiukai II (n=2)	♂ (n=2)	elite (n=1)
			commoner (n=1)
	Santaka-Šventininkai (n=1)	probable ♂ (n=1)	commoner (n=1)
	Sudota (n=2)	presumed ♀ (n=1)	elite (n=1)
		probable ♂ (n=1)	elite (n=1)
	Taurapilis (n=4)*	♂ (n=4)*	chieftain (n=1)
			elite (n=3)*
North–Central Lithuania (n=25)*	Kalniškiai (n=10)	♂ (n=5)	elite (n=3)
			middle rank (n=1)
			commoner (n=1)
		probable ♂ (n=1)	elite (n=1)
		♀ (n=4)	elite (n=2)
			commoner (n=2)
	Plinkaigalis (n=15)*	♂ (n=9)*	elite (n=6)*
			middle rank (n=1)
			commoner (n=2)*
		♀ (n=6)	elite (n=2)
Central Lithuania (n=14)*	Marvelė (n=14)*	♂ (n=6)	elite (n=3)
			middle rank (n=2)
			commoner (n=1)
		probable ♂ (n=3)*	elite (n=1)
			middle rank (n=1)
			commoner (n=1)*
		♀ (n=1)	elite (n=1)
		probable ♀ (n=4)	elite (n=2)
			commoner (n=2)
Western Lithuania (n=19)*	Pagrybis (n=16)*	♂ (n=7)	higher elite (n=1)
			elite (n=4)
			commoner (n=2)
		presumed ♂ (n=1)	elite (n=1)
		probable ♂ (n=1)	elite (n=1)
		♀ (n=4)	elite (n=2)
			commoner (n=2)
		probable ♀ (n=3)*	elite (n=2)
			commoner (n=1)*
	Vėluikiai (n=3)	♂ (n=2)	higher elite (n=1)
			elite (n=1)
		♀ (n=1)	commoner (n=1)
Southern Lithuania (n=1)*	Krikštonys (n=1)*	♂ (n=1)*	elite (n=1)*

* Due to the failure to meet at least one of the collagen quality criterion six samples from Krikštonys. Marvelė 335. Pagrybis 166. Plinkaigalis. 61 and 76. and Taurapilis 1/2 were excluded from further interpretations.

burials contained rich grave goods, including sets of weapons and ornaments of non-local provenance (Bliujienė and Curta 2011; Kliaugaitė and Kurila 2012). Due to poor bone preservation, only one burial from barrow 7 (10), that of a sub-adult individual, possibly a young female as evidenced by the grave goods, was analysed.

In Paduobė-Šaltaliūnė III, 18 barrows were excavated in the period 1987–2008. The discovered burials date to the Late Roman to Viking periods. Barrow 17 contained the only inhumation found in the cemetery, a burial of a male and a horse, which was looted soon after the burial (Steponaitis 2012). The remains of luxurious grave goods (e.g. part of a silver gilded buckle), as well as the very fact of burial together with a horse, allow one to assign the individual to the paramount elite of that time (Bliujienė and Steponaitis 2009).

Pavajuonis-Rėkučiai is a barrow cemetery which lacks precise chronology due to the relative scarcity of excavations. In 1994 and 1996, two Late Roman–Early Migration period barrows were excavated, and in barrow 2 (11), burials of a female and a child were found. Both burials contained sets of multiple imported ornaments, mostly made of silver, testifying to high social status (Semėnas 1998; Bliujienė and Curta 2011). Remains of the female (burial 2) were selected for the study.

In Peršaukštis-Kasčiukai II, a small group of barrows, of which five date to the Late Roman–Early Migration period, were excavated in 2002–2004. Barrow 4 contained three burials. Male burial 3 was distinguished by abundant warrior equipment (two spearheads, an axe, a shield boss and other iron items), although not by precious metals or other luxury items. Another male buried in barrow 6 was accompanied by a weapon set (a spearhead and an axe), which can be considered typical for a commoner male in this region (Kurila and Kliaugaitė 2008).

Santaka-Šventininkai is a barrow cemetery dating to the Migration period. In 2000–2003, six barrows were excavated. Barrow 2 (77) contained two inhumations and two cremations. Burial 1, in which a probable male was interred, was selected for the study. It contained few grave goods, and no weapons or other typically male items (Vaitkevičius 2007).

Sudota barrow cemetery site (not to be confused with the other Sudota barrow cemeteries I–IV) was a group of seven barrows, which was located near the above-mentioned Paduobė-Šaltaliūnė III barrow cemetery and had probably been a part of one single cemetery in the past. In 1988 and 1989, all seven barrows were excavated and both inhumations and cremations dating to the Late Roman–Early Migration period were found. Barrow 1 contained a double inhumation of untypical construction: a male lay on the bottom of a burial pit, and on the top of its fill was a sub-adult, possibly a young female, as suggested by the grave goods. The former had a weapon set and the latter ornaments (Merkevičius 1990). Both individuals were sampled.

In Taurapilis barrow cemetery, 14 barrows were excavated in 1970 and 1971, and the excavations yielded notable results. Five barrows dating to the Late Roman–Early Migration period contained burials of elite warriors. A burial of a military chieftain and his horse was found in barrow 5. He was sent off to the afterlife with a prestigious set of five weapons, including a *spatha* sword, and other warrior equipment, including numerous silver or gilded silver items, a drinking horn, etc. Their origins can be traced in different regions of barbarian Europe (Tautavičius 1981; Anke 1998, p. 134, Fig. 76; Bliujienė and Steponaitis 2009). Three more males, possibly the chieftain's retinue, were buried in barrows 1, 4 and 6, together with horses and weapons, although, substantially fewer luxurious items were found in their burials (Tautavičius 1981; Bliujienė and Steponaitis 2009). The chieftain and three other males were analysed.

The Krikštonys barrow cemetery is located in southern Lithuania, a transit region between the East Lithuanian Barrow culture and the Sudovian culture. This region had distinct burial features, including barrows whose mounds were constructed entirely out of stones and the early spread of cremation (Bliujienė 2016). In 1958, remains of two barrows dating to the Late Roman–Migration period were excavated in Krikštonys. One of them contained the inhumation of a male buried with a drinking horn and prestigious weapons similar to those of the Taurapilis chieftain. However, no other symbols of exceptional wealth and social status were found (Kulikauskas 1959; Bliujienė 2013). This male was the only one to be sampled for stable isotope analysis.

Three of the analysed sites (Kalniškiai, Plinkaigalis and Marvelė) represent central Lithuania. In this region in the 1st millennium AD, the dead were buried in flat cemeteries (burials without any above-ground features) instead of in barrows, of which many were in use throughout many centuries. Inhumation was the sole practice until ca. the mid-1st millennium AD, when cremation started to spread. However, cremation was still rare in the period under discussion (Bertašius 2016).

Kalniškiai is a flat cemetery dated to the Late Roman and Migration periods. Between 1985 and 2004, 256 inhumations and 16 cremations were found. For the analysis, ten individuals were selected. In burial 5, two males (A and B) were buried together, both equipped with rather rich warrior assemblages. In burial 39, another wealthy warrior was buried with two horses (Kazakevičius 1998). Other burials (6, 8, 10, 13, 14, 17 and 20) contained individuals of both sexes and different social groups.

Plinkaigalis flat cemetery was excavated in the period 1977–1984. The excavations yielded 364 inhumations, eight cremations and three horse burials from the Late Roman and Migration periods. The cemetery stands out in terms of abundance and diversity of grave goods. Many individuals were accompanied by sets of luxurious ornaments, weapons and other items, some of them of non-local origin (Kazakevičius 1993). In all, 15 individuals were analysed (11 in this study, while the isotopic data of four individuals from burials 162B, 162C and 336A, 337A are already published; Kurila et al. 2021). Four of them (162B, 162C and 336A, 337A) were interred in group burials together with children; traces of lethal trauma were detected on their skeletons (Kurila et al. 2021). Other males (50, 61, 76, 106, 144, 280 and 332) and females (91, 115, 190 and 224) were selected in order to represent both sexes and different social standings.

Marvelė, the largest known cemetery in Lithuania, was excavated in the period 1991–2013, and 1591 human inhumations and cremations, as well as 236 horse burials, were found. The cemetery dates to a millennium-long period from the Early Roman period to the 13th century AD. Out of 14 analysed burials, four (316, 323, 324 and 325) were concentrated in a small cluster, and some were distinguished by richer grave goods sets. Other burials (176, 193, 194, 213, 282, 284, 312, 335, 1071 and 1075) belonged to males and females and they varied in richness (Bertašius 2005).

In western Lithuania, the dead were also buried uncremated in flat cemeteries in the discussed period. Both the burial practices and the artefacts buried as grave goods were rather similar to those in central Lithuania (Jovaiša 2016; Kiulkys 2016). Two cemeteries (Pagrybis and Vėluikiai) from the region were analysed for the study.

Pagrybis flat cemetery, was excavated in 1980–1982, and 217 burials dating to the Migration period and slightly later were found. In 38 cases, males or even children were accorded horse sacrifices (heads and lower limbs) and many of the males had weapons, which allowed the distinction of several levels of military hierarchy (Vaitkunskienė 1995a; 1995b). However, not all levels were represented in the available skeletal collection. Among the males (62B, 85, 145, 156, 170, 174, 193, 215 and possibly young male 184), mostly higher statuses are represented, and among the females (11, 35, 39, 62A, 166, 176 and 197), both the elites and the commoners are evenly represented. One grave was a double burial of a male and a female (62A, 62B).

In Vėluikiai, three Late Roman and Early Migration period burials were excavated in 2006, and all three discovered humans were included in the study. Males 1 and 3 had weapons, but the grave goods assemblage of burial 3 was considerably larger, and it also included a set of equestrian gear. Female burial 2 contained few grave goods, namely an awl, a pin and a ring (Jovaiša 2007).

1.2 Archaeological assignment of gender and social status

The gender and social group were assigned to the analysed humans according to the presence, variety and abundance of specific grave goods found in the investigated individuals' burials. As archaeological indicators of gender, weapons, other warrior equipment (e.g. shoulder straps, parts of scabbards, drinking horns, etc.), riding gear, and some tools (e.g. gouges and presumably working axes in assemblages lacking weapons) were considered male, while most of the ornaments and weaving tools were considered female. An effort was made to assess the assemblages of each analysed individual's burial in the context of regional traditions (Kurila 2009a; 2009b; Banytė-Rowell 2014). In all burials which had gender markers, these corresponded to the osteologically determined sex. Therefore, in several cases where biological sex determination was impossible, attempts were made to refer to the grave goods in order to determine the individuals' gender (see below).

The idea of grave goods deposited with the deceased and other mortuary variables as an indicator of social status has been advocated since the 1970s (Saxe 1970; Binford 1971; Tainter 1978). Although this approach has been criticised at the theoretical level (Parker Pearson 1993; O'Shea 1995; Chapman 2003), no other relevant methodologies for research have been proposed. This approach was also followed in the current paper.

In all regions, the females were divided into two social groups, the elites and the commoners, referring mostly to the presence/abundance of assemblages of ornaments, the materials of their production and probable imports. There was, however, no universal separation for all regions. All burials were assessed based on their regional and chronological background. Although some variability can be observed within the elite group, it is not extensive enough to be able to make any subdivisions.

The males were all divided into three social groups, although based on somewhat differing criteria in different Lithuanian regions. In eastern Lithuania, the division between the commoners and the elite was made based on weapon sets, particularly the specialised weapons intended only for combat rather than for hunting or to be used as tools, and also other items of warrior equipment. Among the elites, two individuals of the supreme social rank (military chieftains from Taurapilis and Paduobė-Šaltaliūnė III), as evidenced by luxurious imports, horses and other signs of wealth and authority, stand out. For central Lithuania, similar criteria for categorisation into elites and commoners were applied, although the overall regional amount of wealth in cemeteries (e.g. the presence of silver items in higher quantities) was also taken into consideration. No individuals assigned as chieftains were identified here, but within the variety of statuses, the intermediate (middle) rank was assigned to several individuals who had no clear attributes of either the elites or the commoners, e.g. those who had non-specialised weapons but no other symbols of warrior identity. In western Lithuania, horse offerings, riding gear and weapon assemblages were used as indicators of the elite. The chronological differences between Pagrybis and Vėluikiai burials were also considered when making evaluations on individuals' social status. Two burials (Pagrybis 85 and Vėluikiai 3) contained larger and richer sets of grave inventories, likely belonging to mounted military leaders. These males were identified as representatives of the higher elite group.

1.3 Stable isotope analysis

In total, 71 human bone collagen samples, each representing separate individuals, were subjected to $\delta^{13}C$ and $\delta^{15}N$ analyses. The human material was sampled from skeletons, which are currently stored in the repository of Vilnius University's Faculty of Medicine, Department of Anatomy, Histology and Anthropology. The majority of human samples were taken from an occipital part of a skull (58/71), however, in cases where this bone type was not available, other parts of the skull (11/71), one femur, and one tibia were sampled instead (Table 2). In terms of anthropologically determined sex, the analysed human population is represented by 37 males, seven probable males, 17 females and seven probable females. In three more cases where biological determination of sex was impossible, the individuals' gender was instead assigned based on their grave goods; these individuals will be referred to as presumed male (Pagrybis 184) and presumed female (Baliuliai and Sudota) (Table 2). In terms of the individuals' age, the analysed human population is represented by sub-adults (<18 years of age; n=3), young adults (18–29 years of age; n=17), middle adults (30–49 years of age; n=21), old adults (≥50 years of age; n=7) and adults of undetermined age (>18 years of age; n=23) (Table 2). Biological sex and age-at-death determinations of the analysed humans were performed according to standard anthropological methods (Meindl and Lovejoy 1985; Lovejoy et al. 1985; Buikstra and Ubelaker 1994; Martin et al. 2013).

Since no animal bones were available from the investigated sites, the isotopic data of faunal samples from other studies were used instead for the purpose of establishing the isotopic dietary baseline for the analysed humans (Table 3).

Stable carbon and nitrogen isotope analyses were carried out in the Center for Physical Sciences and Technology, Vilnius, Lithuania. Bone collagen extraction was performed according to the acid-alkali-acid (AAA) procedure followed by gelatinisation (Szidat et al. 2017). Stable carbon and nitrogen isotope ratios in the bone collagen samples were measured using an elemental analyser (Thermo FlashEA 1112) connected to an isotope ratio mass spectrometer (Thermo Finnigan Delta Plus Advantage). The repeated measurements of international and in-house standards showed analytical errors for $\delta^{13}C$ and $\delta^{15}N$ to be 0.1‰ and 0.2‰, respectively. Stable isotope data is reported as δ values in permille (‰) relative to international standards: V-PDB (Vienna Pee Dee Belemnite) for $\delta^{13}C$ and AIR (Ambient Inhalable Reservoir) for $\delta^{15}N$.

1.4 Faunal isotopic data from previous studies

For the purpose of establishing the human dietary baseline, the isotopic data of 100 faunal samples which were published in other studies was used (Table 3; Antanaitis-Jacobs et al. 2009; Heron et al. 2015; Piličiauskas et al. 2017a; 2017b; Bliujienė et al. 2020; Simčenka et al. 2022). We preferentially made an effort to choose those faunal samples that were contemporaneous with our studied humans. However, this was possible in only two cases, while the rest of faunal samples date to older periods. Nevertheless, since environmental conditions in Lithuania did not undergo substantial changes that would have caused a significant shift in isotopic compositions of the local ecology, all selected faunal samples dating to older periods than the studied humans were considered to be suitable for human dietary referencing purposes.

The faunal samples chosen from other studies represent the potential food/protein sources that could have been consumed by the studied humans and, according to the differences in their habitat (e.g. terrestrial, freshwater, marine, etc.) and feeding behaviour (e.g. herbivores/omnivores, etc.), these animals were grouped into specific categories or food groups. In total, four of these faunal food groups were distinguished: 1) terrestrial herbivores/omnivores (n=66); 2) freshwater fish (n=10); 3) lagoonal fish (n=5); and 4) marine animals (n=19) (Table 3; Fig. 2).

In order to facilitate the evaluations of dietary protein contributions from each food group distinguished in this study, it was decided to first predict $\delta^{13}C$ and $\delta^{15}N$ ranges of potential human consumers of each of these groups (see Fig. 2). These predictions were made by taking the stable isotope values of each animal assigned to its particular food group and then adding the trophic level enrichment values to $\delta^{13}C$ and $\delta^{15}N$ of each faunal sample. In the literature on this topic, the trophic level enrichment value for $\delta^{13}C$ ranges from 0‰ to 2‰ (Bocherens and Drucker 2003; Drucker and Henry-Gambier 2005; Lee-Thorp 2008; Bocherens et al. 2011), therefore, for the creation of $\delta^{13}C$ expectancy ranges for potential consumers of each food

Table 2. The isotopic data of humans analysed in this study.

No.	Site. burial (barrow/burial) no.	Sex	Age	Age group	Social group	Dating	Analysed bone	$\delta^{13}C$. ‰	$\delta^{15}N$. ‰	Coll. %	N. %	C. %	C/N	C/N. atomic
1	Baliuliai 7 (10)/1	presumed ♀	16–18	sub-adult	commoner	250–426 cal AD	occipital	-21.0	9.3	6.3	15.5	42.7	2.8	3.2
2	Kalniškiai 5A	♂	20–30	young adult	elite	254–420 cal AD	occipital	-21.1	8.9	11.6	15.2	41.5	2.7	3.2
3	Kalniškiai 5B	♂	30–39	middle adult	elite	256–530 cal AD	occipital	-20.9	8.9	10.2	15.7	42.8	2.7	3.2
4	Kalniškiai 6	♂	30–39	middle adult	commoner	ca 300–600 AD	occipital	-20.9	9.9	11.3	15.6	43.6	2.8	3.3
5	Kalniškiai 8	♀	>50	old adult	commoner	ca 300–600 AD	occipital	-21.1	9.1	3.1	15.6	44.1	2.8	3.3
6	Kalniškiai 10	♂	20–29	young adult	middle rank	ca 300–600 AD	occipital	-20.6	9.6	11.2	16.4	44.7	2.7	3.2
7	Kalniškiai 13	probable ♂	30–39	middle adult	elite	ca 350–500 AD	occipital	-21.5	8.6	16.0	15.7	43.8	2.8	3.3
8	Kalniškiai 14	♀	25–30	young adult	elite	ca 350–500 AD	occipital	-21.1	7.9	14.0	15.6	42.8	2.7	3.2
9	Kalniškiai 17	♀	20–29	young adult	elite	ca 300–500 AD	occipital	-21.5	8.4	14.9	17.0	46.4	2.7	3.2
10	Kalniškiai 20	♀	40–49	middle adult	commoner	ca 300–600 AD	occipital	-20.7	8.3	9.4	16.1	44.8	2.8	3.2
11	Kalniškiai 39	♂	>50	old adult	elite	264–538 cal AD	occipital	-20.7	9.2	8.0	15.0	41.0	2.7	3.2

Table 2. Continuation

No.	Site. burial (barrow/burial) no.	Sex	Age	Age group	Social group	Dating	Analysed bone	δ^{13}C. ‰	δ^{15}N. ‰	Coll. %	N. %	C. %	C/N	C/N. atomic
12	Krikštonys	♂	25–34	young adult	elite	251–538 cal AD	occipital	-19.6	11.8	2.7	4.5	12.9	2.9	3.3
13	Marvelė 176	probable ♀	>20	adult	elite	ca 350–450 AD	skull fragment	-20.7	9.5	8.7	16.1	45.2	2.8	3.3
14	Marvelė 193	probable ♂	>30	adult	elite	ca 350–450 AD	skull fragment	-20.3	10.3	1.2	16.7	47.4	2.8	3.3
15	Marvelė 194	♂	>30	adult	commoner	ca 350–450 AD	skull fragment	-20.1	10.4	6.7	15.0	43.1	2.9	3.4
16	Marvelė 213	♂	35–45	middle adult	middle rank	ca 350–550 AD	occipital	-20.2	9.9	11.8	15.5	44.1	2.8	3.3
17	Marvelė 282	probable ♀	>20	adult	elite	ca 350–450 AD	skull fragment	-19.9	9.3	4.6	15.8	44.7	2.8	3.3
18	Marvelė 284	probable ♀	>20	adult	commoner	ca 350–450 AD	skull fragment	-20.3	8.9	3.2	15.6	43.1	2.8	3.2
19	Marvelė 312	♂	30–39	middle adult	elite	ca 350–550 AD	occipital	-20.3	10.1	18.0	16.4	45.7	2.8	3.3
20	Marvelė 316	probable ♀	>20	adult	commoner	ca 350–450 AD	skull fragment	-20.2	9.1	2.0	15.5	43.2	2.8	3.2
21	Marvelė 323	♂	40–49	middle adult	middle rank	ca 350–450 AD	skull fragment	-20.1	10.2	4.9	15.8	43.9	2.8	3.2
22	Marvelė 324	♂	40–49	middle adult	elite	ca 350–450 AD	occipital	-20.0	10.5	16.0	15.9	44.8	2.8	3.3
23	Marvelė 325	♀	30–40	middle adult	elite	381–547 cal AD	occipital	-20.5	9.4	8.3	14.9	40.4	2.7	3.2
24	Marvelė 335	probable ♂	>20	adult	commoner	ca 350–450 AD	skull fragment	-19.7	10.7	0.8	15.6	44.2	2.8	3.3
25	Marvelė 1071	probable ♂	>20	adult	middle rank	210–380 cal AD	occipital	-20.7	10.0	9.0	14.3	39.2	2.7	3.2
26	Marvelė 1075	♂	>30	adult	elite	65–228 cal AD	occipital	-20.2	9.9	6.0	15.4	42.7	2.8	3.2
27	Paduobė-Šaltaliūnė III 17/1	♂	25–30	young adult	chieftain	255–423 cal AD	occipital	-20.6	10.2	6.5	15.5	43.0	2.8	3.2

Table 2. Continuation

No.	Site. burial (barrow/burial) no.	Sex	Age	Age group	Social group	Dating	Analysed bone	δ13C. ‰	δ15N. ‰	Coll. %	N. %	C. %	C/N	C/N. atomic
28	Pagrybis 11	♀	20–25	young adult	elite	ca 400–700 AD	occipital	-21.2	7.7	19.3	15.9	44.3	2.8	3.3
29	Pagrybis 35	probable ♀	>40	adult	elite	ca 400–700 AD	occipital	-21.1	8.7	8.2	16.4	45.6	2.8	3.2
30	Pagrybis 39	♀	25–35	young adult	elite	ca 400–700 AD	occipital	-21.0	8.9	16.7	15.6	43.9	2.8	3.3
31	Pagrybis 62A	probable ♀	25–35	young adult	elite	421–576 cal AD	occipital	-21.3	9.3	1.7	6.3	17.3	2.8	3.2
32	Pagrybis 62B	♂	30–39	middle adult	elite	420–573 cal AD	occipital	-20.7	8.3	3.5	15.7	44.2	2.8	3.3
33	Pagrybis 85	♂	40–49	middle adult	higher elite	560–651 cal AD	occipital	-21.2	7.8	8.5	14.8	40.5	2.7	3.2
34	Pagrybis 145	♂	>20	adult	elite	482–648 cal AD	occipital	-21.0	8.4	6.5	15.0	40.8	2.7	3.2
35	Pagrybis 156	probable ♂	>20	adult	elite	ca 400–700 AD	occipital	-20.9	9.3	13.7	15.8	44.1	2.8	3.3
36	Pagrybis 166	probable ♀	>20	adult	commoner	ca 400–700 AD	right parietal	-20.8	8.4	0.7	15.7	44.5	2.8	3.3
37	Pagrybis 170	♂	>50	old adult	commoner	ca 400–700 AD	occipital	-21.0	9.5	2.3	15.9	44.4	2.8	3.3
38	Pagrybis 174	♂	30–45	middle adult	commoner	ca 400–700 AD	right parietal	-21.1	8.6	1.3	15.6	43.9	2.8	3.3
39	Pagrybis 176	♀	>50	old adult	commoner	ca 400–700 AD	occipital	-21.1	8.7	12.0	16.8	46.1	2.7	3.2
40	Pagrybis 184	presumed ♂	13–18	sub-adult	elite	ca 400–700 AD	skull fragment	-21.0	8.1	14.7	16.2	44.9	2.8	3.2
41	Pagrybis 193	♂	30–40	middle adult	elite	ca 400–700 AD	occipital	-21.2	8.9	13.9	15.9	44.2	2.8	3.2
42	Pagrybis 197	♀	40–49	middle adult	commoner	ca 400–700 AD	occipital	-21.0	8.1	11.4	16.0	45.0	2.8	3.3
43	Pagrybis 215	♂	>40	adult	elite	ca 400–700 AD	occipital	-21.0	8.9	16.7	16.3	44.6	2.7	3.2

Table 2 Continuation

No.	Site. burial (barrow/burial) no.	Sex	Age	Age group	Social group	Dating	Analysed bone	$\delta^{13}C$. ‰	$\delta^{15}N$. ‰	Coll. %	N. %	C. %	C/N	C/N. atomic
44	Pavajuonis-Rėkučiai 2 (11)/2	♀	25–35	young adult	elite	251–408 cal AD	occipital	-20.6	9.6	3.0	8.8	23.4	2.7	3.1
										16.1	13.8	43.3	3.1	3.7
										14.5	14.4	44.8	3.1	3.6
										11.2*		37.2*	3.0*	3.5*
45	Peršaukštis-Kasčiukai II 4/3	♂	>20	adult	elite	240–364 cal AD	occipital	-21.2	9.8	10.7	15.8	43	2.7	3.2
										14.6	13.7	42.3	3.1	3.6
										13.3	13.3	41.5	3.1	3.6
										12.9*		42.3*	3.0*	3.5*
46	Peršaukštis-Kasčiukai II 6/1	♂	>20	adult	commoner	228–424 cal AD	occipital	-20.4	10.3	2.5	7.0	19.2	2.7	3.2
47	Plinkaigalis 50	♂	>40	adult	elite	268–543 cal AD	occipital	-20.6	9.5	3.0	11.7	32.3	2.8	3.2
48	Plinkaigalis 61	♂	25–34	young adult	elite	265–568 cal AD	occipital	-21.4	8.8	1.8	4.7	13.3	2.8	3.3
49	Plinkaigalis 76	♂	30–39	middle adult	commoner	235–430 cal AD	occipital	-21.4	8.2	1.7	3.9	11.2	2.9	3.3
50	Plinkaigalis 91	♀	>50	old adult	commoner	265–566 cal AD	occipital	-20.4	8.3	2.1	7.0	18.7	2.7	3.1
51	Plinkaigalis 106	♂	40–49	middle adult	elite	258–550 cal AD	occipital	-20.8	8.4	2.1	6.7	17.8	2.7	3.1
52	Plinkaigalis 115	♀	20–29	young adult	elite	435–602 cal AD	occipital	-20.7	10.5	9.8	16.7	45.5	2.7	3.2
53	Plinkaigalis 144	♂	>50	old adult	elite	414–600 cal AD	occipital	-21.0	8.0	2.2	7.5	20.4	2.7	3.2

Table 2. Continuation

No.	Site. burial (barrow/burial) no.	Sex	Age	Age group	Social group	Dating	Analysed bone	δ¹³C. ‰	δ¹⁵N. ‰	Coll. %	N. %	C. %	C/N	C/N. atomic
54	Plinkaigalis 162B	♂	35–45	middle adult	commoner	260–530 cal AD	occipital	-21.2	8.9	1.6	6.5	17.7	2.7	3.2
										3.0	8.4	23.2	2.8	3.2
										2.3*	7.4*	20.4*	2.8*	3.2*
55	Plinkaigalis 162C	♀	>20	adult	commoner	260–414 cal AD	occipital	-21.2	7.9	2.9	9.4	25.8	2.8	3.2
											8.9	24.6	2.8	3.2
											9.3	25.7	2.8	3.2
										2.9*	9.2*	25.3*	2.8*	3.2*
56	Plinkaigalis 190	♀	>50	old adult	commoner	428–589 cal AD	occipital	-20.7	9.1	3.0	12.9	35.7	2.8	3.2
57	Plinkaigalis 224	♀	20–29	young adult	elite	248–534 cal AD	occipital	-21.1	8.9	2.1	8.9	23.8	2.7	3.1
58	Plinkaigalis 280	♂	>40	adult	middle rank	241–402 cal AD	occipital	-20.6	9.2	8.8	14.2	38.8	2.7	3.2
59	Plinkaigalis 332	♂	40–49	middle adult	elite	383–590 cal AD	occipital	-20.8	9.4	1.6	6.2	17.0	2.7	3.2
60	Plinkaigalis 336A	♂	25–34	young adult	elite	242–350 cal AD	occipital	-20.8	8.6	1.6	7.8	21.1	2.7	3.2
										1.8	6.1	16.9	2.8	3.3
											5.4	14.9	2.8	3.3
											9.0	24.6	2.7	3.2
										1.7*	7.1*	19.4*	2.8*	3.2*
61	Plinkaigalis 337A	♀	>25	adult	commoner	250–407 cal AD	occipital	-20.8	8.3	10.8	16.0	43.6	2.7	3.2
62	Santaka-Šventininkai 2 (77)/1	probable ♂	>30	adult	commoner	416–558 cal AD	occipital	-20.0	9.6	8.4	14.9	40.7	2.7	3.2

Table 2. Continuation

No.	Site. burial (barrow/burial) no.	Sex	Age	Age group	Social group	Dating	Analysed bone	δ¹³C. ‰	δ¹⁵N. ‰	Coll. %	N. %	C. %	C/N	C/N. atomic
63	Sudota 1/central	presumed ♀	10–18	sub-adult	elite	ca 350–450 AD	right femur	-19.9	9.8	9.8	16.0	44.4	2.8	3.2
64	Sudota 1/central	probable ♂	>20	adult	elite	ca 350–450 AD	right tibia	-20.9	10.3	9.2	15.9	44.4	2.8	3.3
65	Taurapilis 1/2	♂	40–49	middle adult	elite	245–534 cal AD	occipital	-21.5	10.0	2.4	3.3	9.2	2.8	3.3
66	Taurapilis 4/1	♂	25–35	young adult	elite	244–401 cal AD	occipital	-22.0	9.5	15.1	15.5	42.1	2.7	3.2
67	Taurapilis 5/1	♂	45–54	middle adult	chieftain	260–420 cal AD	occipital	-21.4	10.9	5.4	16.1	45.0	2.8	3.3
68	Taurapilis 6/1	♂	>30	adult	elite	244–404 cal AD	occipital	-21.9	9.4	4.5	13.0	35.7	2.8	3.2
69	Vėluikiai 1	♂	18–20	young adult	elite	ca 300–450 AD	occipital	-21.1	8.5	15.5	16.8	47.5	2.8	3.3
70	Vėluikiai 2	♀	25–30	young adult	commoner	ca 350–450 AD	occipital	-21.4	8.0	4.4	15.7	44.1	2.8	3.3
71	Vėluikiai 3	♂	35–44	middle adult	higher elite	246–406 cal AD	occipital	-21.4	8.7	12.2	16.1	43.7	2.7	3.2

* These values of individuals from Pavajuonis-Rėkučiai 2 (11)/2. Peršaukštis-Kasčiukai II 4/3. Plinkaigalis 162B. 162C. and 336A are the averages of %. N %. C %. C/N. C/N atomic values measured from multiple samples of the same individuals. For more information on Plinkaigalis individuals. see Kurila et al. (2021

Table 3. The isotopic data of animals used in this paper from other studies.

No.	Site	Species	Food group	Chronology	δ13C (‰)	δ15N (‰)	References
1	Daktariškė 5	auroch or bison	herbivore or omnivore	Subneolithic – Early Bronze Age	-22.4	5.6	Simčenka et al. 2022
2	Kretuonas 1D	auroch or bison	herbivore or omnivore	Early Bronze Age	-22.3	3.1	Antanaitis-Jacobs et al. 2009
3	Šventoji 4	auroch or bison	herbivore or omnivore	Subneolithic	-22.6	5.1	Piličiauskas et al. 2017a
4	Šventoji 43	auroch or bison	herbivore or omnivore	Subneolithic	-22.4	3.4	Piličiauskas et al. 2017a
5	Žemaitiškė 2	auroch or bison	herbivore or omnivore	Subneolithic	-22.6	5.1	Piličiauskas et al. 2017b
6	Žemaitiškė 2	auroch or bison	herbivore or omnivore	Subneolithic	-22.9	5.4	Piličiauskas et al. 2017b
7	Turlojiškė	beaver	herbivore or omnivore	Late Bronze Age	-22.0	4.5	Simčenka et al. 2022
8	Šventoji 3	beaver	herbivore or omnivore	Subneolithic	-22.1	5.4	Antanaitis-Jacobs et al. 2009
9	Šventoji 9	beaver	herbivore or omnivore	Early Bronze Age	-22.9	4.5	Piličiauskas et al. 2017a
10	Žemaitiškė 2	beaver	herbivore or omnivore	Subneolithic	-22.6	5.6	Piličiauskas et al. 2017b
11	Žemaitiškė 2	beaver	herbivore or omnivore	Subneolithic	-23.9	4.8	Antanaitis-Jacobs et al. 2009
12	Žemaitiškė 2	beaver	herbivore or omnivore	Subneolithic	-22.0	5.5	Piličiauskas et al. 2017b
13	Žemaitiškė 2	beaver	herbivore or omnivore	Subneolithic	-23.0	3.5	Antanaitis-Jacobs et al. 2009
14	Daktariškė 5	boar	herbivore or omnivore	Subneolithic – Early Bronze Age	-23.5	3.9	Simčenka et al. 2022
15	Daktariškė 5	boar	herbivore or omnivore	Subneolithic – Early Bronze Age	-21.9	4.4	Simčenka et al. 2022
16	Garniai	boar	herbivore or omnivore		-20.9	6.2	Simčenka et al. 2022
17	Šventoji 3	boar	herbivore or omnivore	Subneolithic	-21.7	5.5	Antanaitis-Jacobs et al. 2009
18	Šventoji 6	boar	herbivore or omnivore	Subneolithic	-21.6	5.3	Antanaitis-Jacobs et al. 2009
19	Žemaitiškė 1	boar	herbivore or omnivore	Subneolithic	-23.3	6.5	Antanaitis-Jacobs et al. 2009
20	Žemaitiškė 2	boar	herbivore or omnivore	Subneolithic	-23.1	4.6	Piličiauskas et al. 2017b
21	Žemaitiškė 2	boar	herbivore or omnivore	Subneolithic	-22.4	4.1	Piličiauskas et al. 2017b
22	Daktariškė 5	boar/pig	herbivore or omnivore	Subneolithic – Early Bronze Age	-22.1	4.3	Simčenka et al. 2022
23	Daktariškė 5	boar/pig	herbivore or omnivore	Subneolithic – Early Bronze Age	-22.3	4.3	Simčenka et al. 2022
24	Turlojiškė	boar/pig	herbivore or omnivore	Late Bronze Age	-21.6	6.0	Simčenka et al. 2022
25	Kretuonas 1B	boar/pig	herbivore or omnivore	Subneolithic	-23.6	6.4	Antanaitis-Jacobs et al. 2009

Table 3. Continuation

No.	Site	Species	Food group	Chronology	δ13C (‰)	δ15N (‰)	References
26	Šventoji 1B	boar/pig	herbivore or omnivore	Subneolithic	-21.8	4.1	Antanaitis-Jacobs et al. 2009
27	Šventoji 3	boar/pig	herbivore or omnivore	Subneolithic	-21.3	3.8	Antanaitis-Jacobs et al. 2009
28	Šventoji 43	boar/pig	herbivore or omnivore	Subneolithic	-22.2	6.9	Piličiauskas et al. 2017a
29	Žemaitiškė 2	boar/pig	herbivore or omnivore	Subneolithic	-21.4	3.8	Piličiauskas et al. 2017b
30	Mineikiškės	bream	freshwater fish	Late Bronze Age	-20.5	6.1	Simčenka et al. 2022
31	Mineikiškės	bream	freshwater fish	Late Bronze Age	-20.8	5.6	Simčenka et al. 2022
32	Turlojiškė	bream	freshwater fish	Late Bronze Age	-25.8	7.4	Simčenka et al. 2022
33	Turlojiškė	bream	freshwater fish	Late Bronze Age	-25.9	7.6	Simčenka et al. 2022
34	Daktariškė 5	cattle	herbivore or omnivore	Early Bronze Age?	-22.5	5.3	Simčenka et al. 2022
35	Garniai	cattle	herbivore or omnivore	Late Bronze Age	-21.5	6.3	Simčenka et al. 2022
36	Luokesa 1	cattle	herbivore or omnivore	Late Bronze Age	-21.6	5.3	Simčenka et al. 2022
37	Mineikiškės	cattle	herbivore or omnivore	Late Bronze Age	-21.1	5.3	Simčenka et al. 2022
38	Turlojiškė	cattle	herbivore or omnivore	Late Bronze Age	-21.1	7.4	Antanaitis-Jacobs et al. 2009
39	Žemaitiškė 2	cattle	herbivore or omnivore	Subneolithic	-22.7	4.8	Piličiauskas et al. 2017b
40	Turlojiškė	cattle newborn	herbivore or omnivore	Late Bronze Age	-21.3	8.3	Simčenka et al. 2022
41	Daktariškė 5	elk	herbivore or omnivore	Subneolithic – Early Bronze Age	-23.8	5.6	Simčenka et al. 2022
42	Luokesa 1	elk	herbivore or omnivore	Late Bronze Age	-22.7	3.4	Simčenka et al. 2022
43	Šventoji 1B	elk	herbivore or omnivore	Subneolithic	-23.1	3.6	Antanaitis-Jacobs et al. 2009
44	Šventoji 4	elk	herbivore or omnivore	Subneolithic	-23.6	4.9	Antanaitis-Jacobs et al. 2009
45	Šventoji 43	elk	herbivore or omnivore	Subneolithic	-23.5	4.4	Piličiauskas et al. 2017a
46	Žemaitiškė 2	elk	herbivore or omnivore	Subneolithic	-22.9	4.1	Piličiauskas et al. 2017b
47	Žemaitiškė 2	elk	herbivore or omnivore	Subneolithic	-23.1	4.1	Piličiauskas et al. 2017b
48	Šventoji 4	flounder	marine animal	Subneolithic	-16.6	11.6	Antanaitis-Jacobs et al. 2009
49	Šventoji 23	grey seal	marine animal	Subneolithic	-16.5	12.7	Antanaitis-Jacobs et al. 2009
50	Šventoji 43	grey seal	marine animal	Subneolithic	-16.9	11.7	Piličiauskas et al. 2017a
51	Šventoji 1B	harbour seal	marine animal	Subneolithic	-15.5	13.1	Antanaitis-Jacobs et al. 2009

Table 3. Continuation

No.	Site	Species	Food group	Chronology	δ13C (‰)	δ15N (‰)	References
52	Šventoji 4	harbour seal	marine animal	Subneolithic	-16.1	12	Antanaitis-Jacobs et al. 2009
53	Šventoji 3	harp seal	marine animal	Subneolithic	-15.6	11.3	Piličiauskas et al. 2017a
54	Šventoji 43	harp seal	marine animal	Subneolithic	-16.5	12.7	Piličiauskas et al. 2017a
55	Šventoji 6	harp seal	marine animal	Subneolithic	-16.6	13.3	Antanaitis-Jacobs et al. 2009
56	Šventoji 23	otter or seal?	marine animal	Subneolithic	-16.5	13.8	Antanaitis-Jacobs et al. 2009
57	Šventoji 4	perch	lagoonal fish	Subneolithic	-20.0	10.6	Piličiauskas et al. 2017a
58	Daktariškė 5	pig	herbivore or omnivore	Early Bronze Age?	-21.7	4.5	Simčenka et al. 2022
59	Garniai	pig	herbivore or omnivore	Late Bronze Age	-22.0	6.1	Simčenka et al. 2022
60	Luokesa 1	pig	herbivore or omnivore	Late Bronze Age	-21.4	6.2	Simčenka et al. 2022
61	Mineikiškės	pig	herbivore or omnivore	Late Bronze Age	-20.9	5.4	Simčenka et al. 2022
62	Mineikiškės	pig	herbivore or omnivore	Late Bronze Age	-19.4	7.4	Simčenka et al. 2022
63	Turlojiškė	pig	herbivore or omnivore	Late Bronze Age	-21.3	5.0	Simčenka et al. 2022
64	Daktariškė 5	pig	herbivore or omnivore	Bronze Age?	-21.7	4.5	Piličiauskas et al. 2017b
65	Eketė	pig	herbivore or omnivore	Migration Period	-22.3	7.4	Bliujienė et al. 2020
66	Šventoji 4	pike	lagoonal fish	Subneolithic	-22.1	9.5	Piličiauskas et al. 2017a
67	Šventoji 4	pike	lagoonal fish	Subneolithic	-21.6	12.6	Antanaitis-Jacobs et al. 2009
68	Luokesa 1	pike	freshwater fish	Late Bronze Age	-22.3	9.3	Simčenka et al. 2022
69	Mineikiškės	pike	freshwater fish	Late Bronze Age	-18.9	8.4	Simčenka et al. 2022
70	Mineikiškės	pike	freshwater fish	Late Bronze Age	-20.7	9.6	Simčenka et al. 2022
71	Turlojiškė	pike	freshwater fish	Late Bronze Age	-23.7	9.6	Simčenka et al. 2022
72	Turlojiškė	pike	freshwater fish	Late Bronze Age	-26.8	12.0	Simčenka et al. 2022
73	Turlojiškė	pike	freshwater fish	Late Bronze Age	-25.7	9.3	Simčenka et al. 2022
74	Šventoji 4	pikeperch	lagoonal fish	Subneolithic	-22.6	10.9	Piličiauskas et al. 2017a
75	Šventoji 4	pikeperch	lagoonal fish	Subneolithic	-21.8	12.6	Antanaitis-Jacobs et al. 2009
76	Daktariškė 5	red deer	herbivore or omnivore	Subneolithic – Early Bronze Age	-23.1	4.9	Simčenka et al. 2022
77	Daktariškė 5	red deer	herbivore or omnivore	Subneolithic – Early Bronze Age	-23.2	5.0	Simčenka et al. 2022

Table 3. Continuation

No.	Site	Species	Food group	Chronology	δ^{13}C (‰)	δ^{15}N (‰)	References
78	Kretuonas 1C	red deer	herbivore or omnivore	Subneolithic	-23.1	5.0	Simčenka et al. 2022
79	Turlojiškė	red deer	herbivore or omnivore	Late Bronze Age	-22.9	5.5	Simčenka et al. 2022
80	Turlojiškė	red deer	herbivore or omnivore	Late Bronze Age	-22.8	4.1	Simčenka et al. 2022
81	Turlojiškė	red deer	herbivore or omnivore	Late Bronze Age	-22.5	5.5	Antanaitis-Jacobs et al. 2009
82	Žemaitiškė 1	red deer	herbivore or omnivore	Subneolithic	-24.1	4	Antanaitis-Jacobs et al. 2009
83	Žemaitiškė 2	red deer	herbivore or omnivore	Subneolithic	-22.3	5.4	Piličiauskas et al. 2017b
84	Žemaitiškė 2	red deer	herbivore or omnivore	Subneolithic	-23.2	4.2	Piličiauskas et al. 2017b
85	Šventoji 1B	ringed seal	marine animal	Subneolithic	-16.5	11.1	Antanaitis-Jacobs et al. 2009
86	Šventoji 4	ringed seal	marine animal	Subneolithic	-15.8	12.4	Antanaitis-Jacobs et al. 2009
87	Šventoji 4	ringed seal	marine animal	Subneolithic	-18.7	13.9	Antanaitis-Jacobs et al. 2009
88	Šventoji 6	ringed seal	marine animal	Subneolithic	-17.1	12.6	Antanaitis-Jacobs et al. 2009
89	Nida	roe deer	herbivore or omnivore	Neolithic	-21.0	6.1	Piličiauskas et al. 2017b
90	Šventoji 43	roe deer	herbivore or omnivore	Subneolithic	-23.5	4.5	Piličiauskas et al. 2017a
91	Luokesa 1	sheep	herbivore or omnivore	Late Bronze Age	-21.7	5.3	Simčenka et al. 2022
92	Mineikiškės	sheep	herbivore or omnivore	Late Bronze Age	-21.0	6.9	Simčenka et al. 2022
93	Mineikiškės	sheep	herbivore or omnivore	Late Bronze Age	-21.2	7.1	Simčenka et al. 2022
94	Eketė	sheep	herbivore or omnivore	Migration Period	-21.8	10.3	Bliujienė et al. 2020
95	Nida	true seals	marine animal	Neolithic	-15.9	13.4	Piličiauskas et al. 2017b
96	Šventoji 4	true seals	marine animal	Subneolithic	-15.3	13.1	Heron et al. 2015
97	Šventoji 4	true seals	marine animal	Subneolithic	-16.6	12	Heron et al. 2015
98	Šventoji 4	true seals	marine animal	Subneolithic	-17.7	10.6	Antanaitis-Jacobs et al. 2009
99	Šventoji 4	true seals	marine animal	Subneolithic	-16.3	12.2	Antanaitis-Jacobs et al. 2009
100	Šventoji 4	true seals	marine animal	Subneolithic	-16.3	15.5	Heron et al. 2015

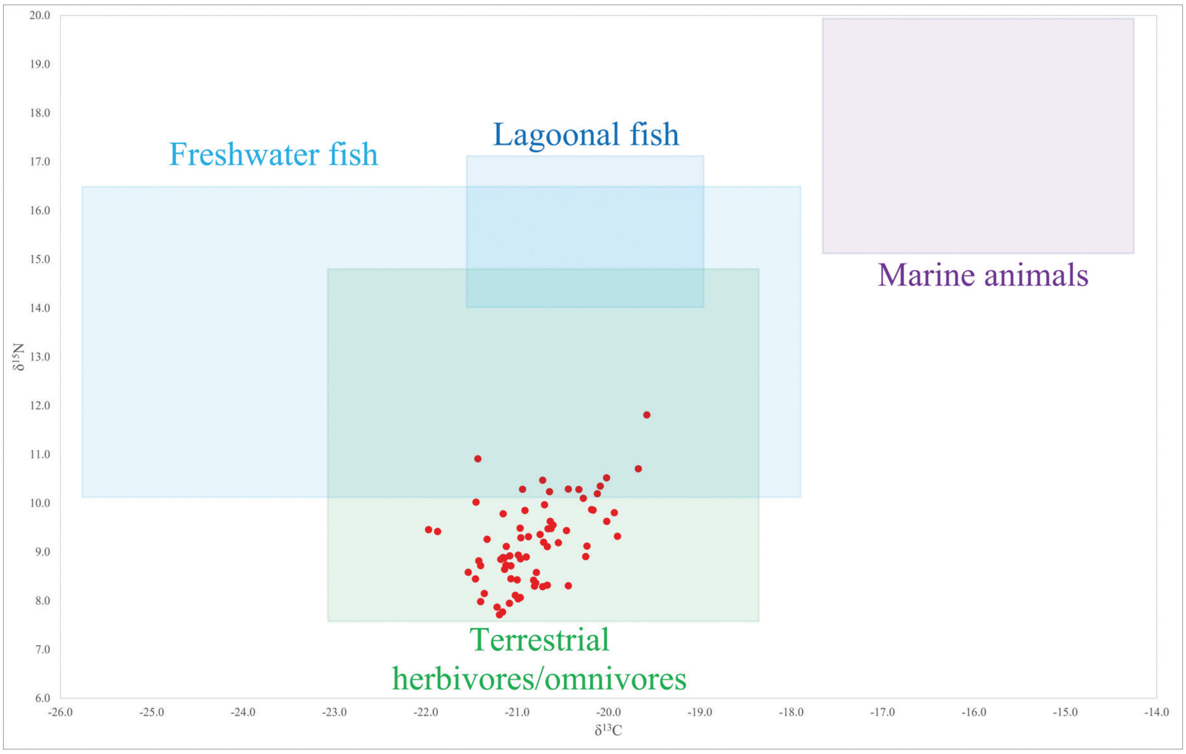

Figure 2. Human stable isotope values transposed against $\delta^{13}C$ and $\delta^{15}N$ expectancy ranges for potential consumers of four different food groups represented by distinctly coloured transparent rectangles (created by Simčenka).

group, the approximate average of those ranges, 1‰, was used (Fig. 2). Meanwhile, there is less agreement regarding the trophic level enrichment factor for $\delta^{15}N$, which in different studies ranges from approximately 3‰ to 6‰ (Bocherens and Drucker 2003; Hedges and Reynard 2007; O'Connell et al. 2012), which is why it was decided that, for the creation of $\delta^{15}N$ expectancy ranges for potential consumers of each food group, the approximate average of that range, 4.5‰, would be used (Fig. 2).

1.5 Radiocarbon dating

Of the 71 analysed individuals, 37 were directly AMS radiocarbon dated (Table 2). The results are published in other papers (Kurila 2020; Kurila et al. 2021; 2023). Although the primary focus of the study in terms of chronology was the Migration period (late 4th–mid-6th century AD), radiocarbon dating demonstrated that some of the selected burials were actually earlier or later. Radiocarbon dating of some of the burials allows them to be assigned to the Late Roman period (ca. 250–400 cal AD), and one burial (Marvelė 1075) is even earlier (65–228 cal AD). Two dated burials from Pagrybis 85 and 145 may be somewhat later than the formal end of the Migration period (post-568 AD). Dating of 34 other burials was established based on the grave goods and other archaeological criteria, i.e. burial constructions, adjacent burials, etc.

1.6 Statistical analysis

The parametric Student's t-test was used to compare the isotopic data between different regional, sex, age and social groups (the results of these statistical comparisons are summarised in Appendices A and B). All statistical calculations were performed with the XLSTAT add-in of Microsoft Excel 2021 software.

2. Results and discussion

2.1 Evaluating collagen quality in bone samples

In order to evaluate reliability of the determined $\delta^{13}C$ and $\delta^{15}N$ values in bone collagen samples, four collagen quality parameters, which are also measured in the same bone samples, were used as indicators of collagen preservation: the percentage of preserved collagen (or collagen yield), carbon and nitrogen concentrations (or %C and %N, respectively) and an atomic ratio between carbon and nitrogen (or C/N) (DeNiro 1985; Ambrose 1990; Van Klinken 1999). Collagen yield in bone samples must reach at least 1% (Van Klinken 1999); %C and %N concentrations in bone collagen should be within the ranges of 15.3%–47% and 5.5%–17.3%, respectively (Ambrose 1990). Finally, the C/N ratio in a bone collagen sample must be within the range of 2.9–3.6 (DeNiro 1985). Any samples which failed to meet any of these collagen quality criteria should be excluded from further analysis and interpretation.

All analysed human samples have C/N ratios which fall within the accepted range, thus indicating the reliability of their isotopic data (DeNiro 1985). It must be noted that the individual from Pavajuonis-Rėkučiai 2 (11)/2, whose bone collagen sample was measured in triplicate (Table 2), had a C/N ratio of one of its measurements that was outside the acceptable range (3.7; Table 2). Nevertheless, it was still decided to include the average δ^{13}C and δ^{15}N values of all three subsamples from this individual since the mean C/N ratio of all three subsamples (3.5) is within the accepted range (Table 2). Furthermore, it must be noted that six samples had at least one other collagen quality criterion that fell below the accepted thresholds (Table 2). Two samples (Marvelė 335 and Pagrybis 166) had a collagen yield that was below 1% (Table 2), and therefore these individuals were excluded from further dietary analysis. Meanwhile, four samples (Krikštonys, Plinkaigalis 61 and 76 and Taurapilis 1/2) had %C and %N that were below the low ends of their respective ranges (15.3% and 5.5%, respectively; Ambrose 1990; Table 2). These four individuals, therefore, were also excluded from further dietary study.

2.2 Human isotopic data

The average δ^{13}C and δ^{15}N values for all successfully analysed humans (n=65) are 20.8±0.5‰ and 9.1±0.8‰, respectively. Overall, the isotopic data of the analysed humans cluster most closely to terrestrial herbivore/omnivore, and, to a lesser extent, to freshwater fish dietary expectancy ranges (Figs. 2 and 3). No statistically significant dietary differences were detected between different social groups (Fig. 4; Appendices A.3–7; B.3–7). However, when comparing all analysed individuals on the basis of their sex, males on average had statistically significantly higher δ^{15}N values compared to females (Fig. 5; Appendix B.1, 2). Furthermore, clear isotopic differences can be seen between individuals from different parts of Lithuania, according to which five different regions could be distinguished: eastern Lithuania, central Lithuania, north-central Lithuania, western Lithuania, and southern Lithuania (the diet in the last region will not be discussed further since it is represented by only one individual from Krikštonys, whose bone collagen sample failed to yield reliable isotopic data; Fig. 6).

2.3 Diet in eastern Lithuania

From the eastern Lithuanian barrow cemeteries of Baliuliai, Paduobė-Šaltaliūnė III, Pavajuonis-Rėkučiai,

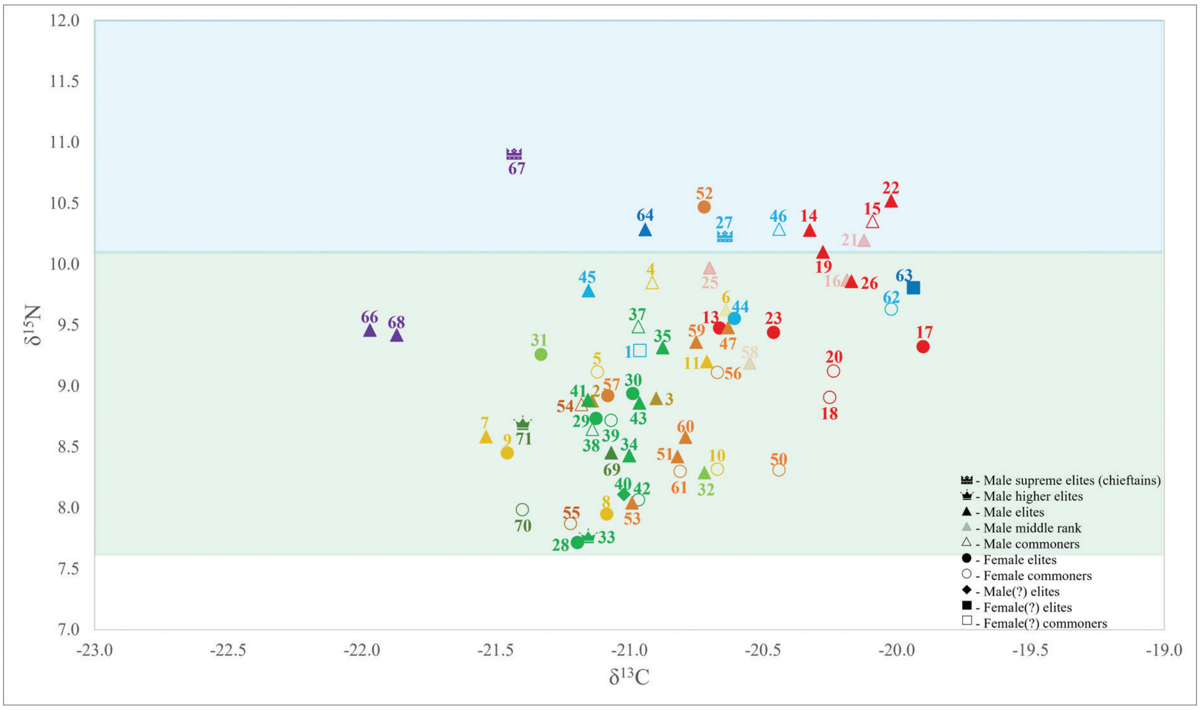

Figure 3. The zoomed-in diagram of human stable isotope values transposed against δ^{13}C and δ^{15}N expectancy ranges for potential consumers of two different food groups: terrestrial herbivores/omnivores (green rectangle) and freshwater fish (blue rectangle). Numbers by each data point correspond to each site's number listed in Tables 2 and 3. The colour of each data point reflects the site or Lithuanian region in question. Double graves from the same burial are also denoted by separate colours (created by Simčenka).

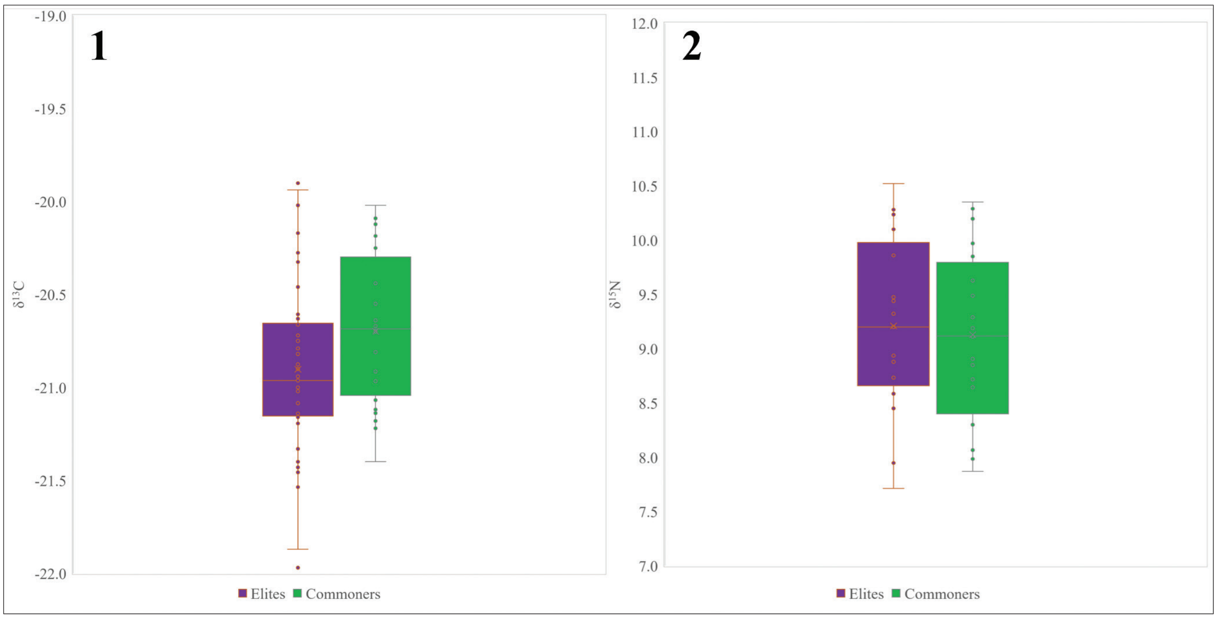

Figure 4. Box and whiskers plots for $\delta^{13}C$ (picture 1) and $\delta^{15}N$ (picture 2) values of humans belonging to different social groups: elites (n=41), commoners (n=24). Note that the elite group also includes chieftains and higher elites, while individuals assigned to the middle rank were combined with commoners (created by Simčenka).

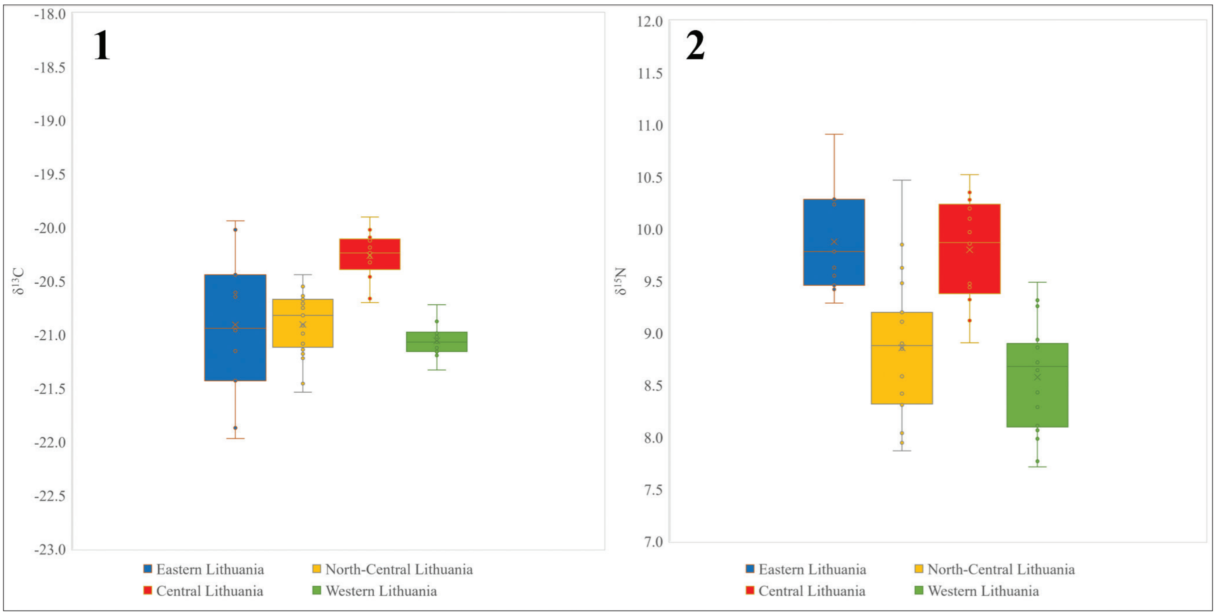

Figure 5. Box and whiskers plots for $\delta^{13}C$ (picture 1) and $\delta^{15}N$ (picture 2) values of humans from different Lithuanian regions: eastern Lithuania (n=11), north-central Lithuania (n=23), central Lithuania (n=13), western Lithuania (n=18) (created by Simčenka).

Peršaukštis-Kasčiukai II, Santaka-Šventininkai, Sudota and Taurapilis, out of 16 analysed samples (which represent 12 individuals), 14 yielded reliable stable isotope values. The $\delta^{13}C$ and $\delta^{15}N$ values in two individuals from Pavajuonis-Rėkučiai 2 (11)/2 and Peršaukštis-Kasčiukai II 4/3 were measured in triplicate (three measurements from the same bone samples) and in both cases repeated measurements yielded very similar stable isotope values (although one of the samples from Pavajuonis-Rėkučiai 2 (11)/2 exceeded its C/N ratio, making its stable isotope values unreliable; Table 2), which is why only the averages of their $\delta^{13}C$ and $\delta^{15}N$ values were included in all diagrams and statistical analysis. The investigated population (which included only individuals with reliable isotopic data) from this region is composed of eight males (two supreme elites/chieftains, four elites, and two commoners), and one female (elite) (Table 2). The average $\delta^{13}C$ and

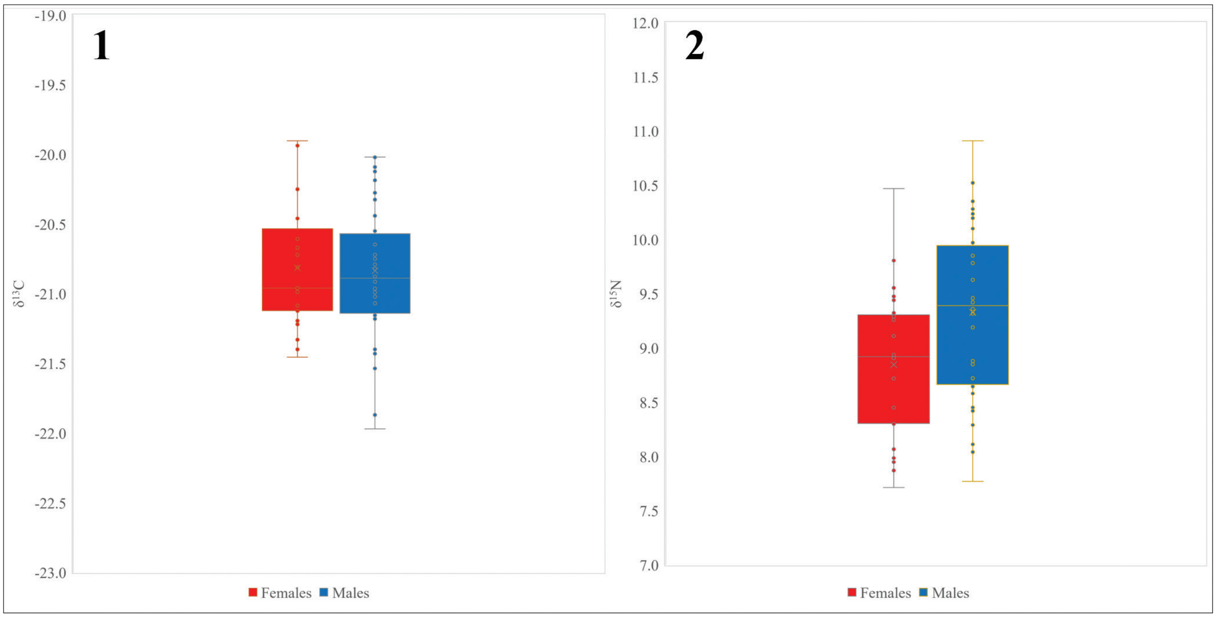

Figure 6. Box and whiskers plots for $\delta^{13}C$ (picture 1) and $\delta^{15}N$ (picture 2) values of humans belonging to different sexes: males (n=40), females (n=25). Note that probable and presumed males/females were also included in their respective groups (created by Simčenka).

$\delta^{15}N$ values of individuals from eastern Lithuanian sites are -20.9±0.7‰ and 9.9±0.5‰, respectively. These results suggest a diet based on varying proportions of terrestrial herbivore/omnivore protein sources, as well as, in some cases, the potential dietary contribution of freshwater fish (Fig. 7). No statistically significant isotopic differences between sex, age or social groups were detected (Appendices A.38; B.38), while, due to insufficient sample sizes, it was impossible to statistically compare different sex or age groups.

According to the isotopic data of humans from eastern Lithuanian barrow cemeteries, it can be suggested that eight analysed individuals subsisted primarily on terrestrial herbivore/omnivore protein sources, whereas the diets of the remaining four people included a more substantial portion of freshwater fish, along with terrestrial animal protein sources (Fig. 7). A few of the most noteworthy cases will be discussed below.

One of the most notable results to discuss are those of the chieftain from Taurapilis 5/1 (no. 67), whose isotopic data, which significantly differ from those of other two males buried in the adjacent barrows, suggest a dietary composition dominated by either exclusively high proportions of terrestrial herbivores/omnivores or some combination of faunal and freshwater fish protein sources (Figs. 3 and 7). What makes this finding even more interesting is the fact that his measured $^{87}Sr/^{86}Sr$ ratios suggest non-local origin (unpublished data), which may partly explain such an isotopically noticeable difference in diet compared to the other two individuals from Taurapilis (Fig. 3). In other words, the significantly different stable isotope values of this male might partially reflect an isotopic composition of the local ecology in both his earlier place of residence, which was located outside of his burial site's environment or even Lithuania as a whole, and the residential area near his barrow. However, it also cannot be ruled out that his exceptionally high social status could have been a contributing or even the main factor in his noticeably higher $\delta^{15}N$ values.

Another noteworthy result was that of the supreme elite male (chieftain) from Paduobė-Šaltaliūnė III (no. 27), whose isotopic data is within both terrestrial animal and freshwater fish expectancy ranges. This result could indicate either a substantially higher dietary proportion of terrestrial animals or some combination of faunal and freshwater fish protein sources (Figs. 3 and 7). However, the second scenario should probably be ruled out since the $\delta^{13}C$, $\delta^{15}N$ and AMS ^{14}C values of the horse which was buried together with this human in the same grave do not suggest any significant dietary input from freshwater sources (Table 2). This result is relevant because AMS ^{14}C dates for both human and horse are too similar (255–423 and 256–424 cal AD) to suggest any significant freshwater reservoir effect on the human radiocarbon sample, which would have made the resulting ^{14}C date seem older than it actually was if aquatic food sources had played a significant enough dietary role in this individual's life (cf. Kurila 2020; Piličiauskienė et al. 2022). Therefore, the first scenario of a potential diet based mainly on terrestrial C_3 animal protein sources, at this juncture, should be considered as the most likely explanation for this individual's isotopic data.

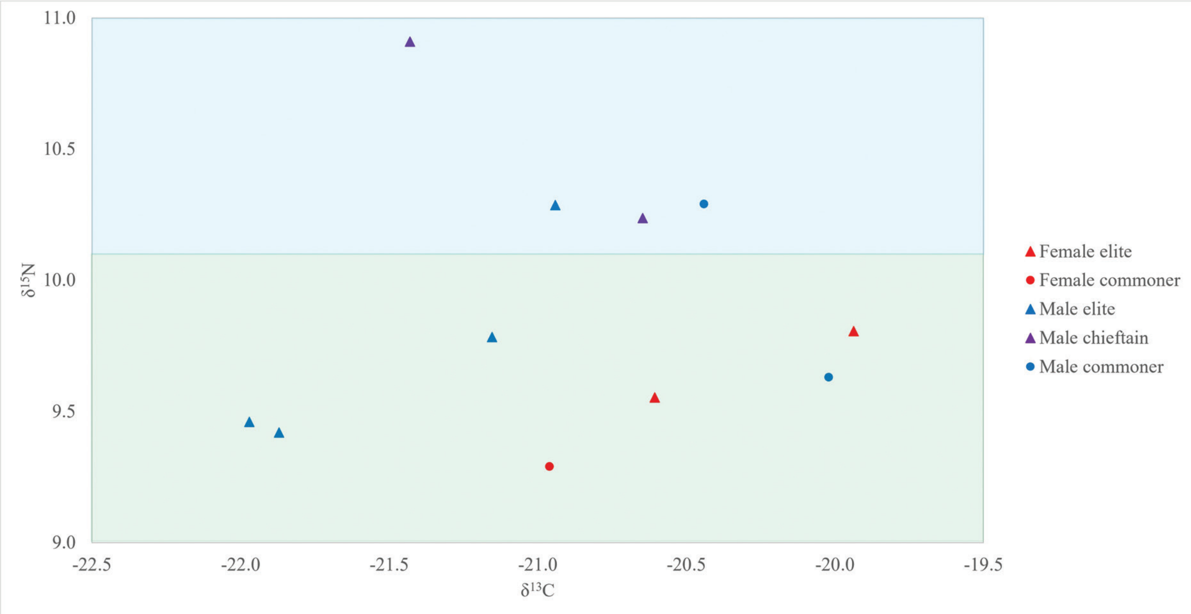

Figure 7. Scatter plot diagram of stable isotope values belonging to humans from eastern Lithuania (created by Simčenka).

Another interesting result was found in the isotopic data of the male (no. 64) and presumed female (no. 63) elites from the double burial of Sudota 1/central. Their stable isotope values suggest a slight dietary difference between the two, with the male consuming a larger proportion of animal and/or freshwater fish protein sources compared to the female, whose isotopic data suggest no or negligible protein contribution from freshwater fish (Figs. 3 and 7). Furthermore, the fact that the $\delta^{13}C$ and $\delta^{15}N$ values of the presumed female are less negative and lower, respectively, compared to those of the male might suggest an additional minor contribution from C_4 plant (millet) protein sources to the former's diet. This suggestion is possible because, from the current archaeobotanical data, it is known that cultivation of millet had started in Lithuania from at least the Late Bronze Age or potentially even as early as the Late Neolithic (Antanaitis-Jacobs et al. 2004; Pollmann 2014; Minkevičius et al. 2020). However, it must be noted that millet grains were far less frequently found in archaeological contexts dating to the first half of 1st millennium AD (Minkevičius 2020), which could either mean that this dietary interpretation must be rejected or that it is correct and that the archaeological evidence for millet consumption has just not been found yet.

Another interesting observation was made when comparing the aforementioned elite males from Paduobė-Šaltaliūnė III (no. 27) and Sudota (no. 64), two barrow cemeteries located very close to each other (Fig. 1). Both the $\delta^{13}C$ and $\delta^{15}N$ values of these individuals were very similar, which could be an indication that, due to their high social status, these particular individuals enjoyed a (presumably) better diet composed of higher proportions of animal and/or freshwater fish protein sources compared to that of commoners (Fig. 3).

2.4 Diet in north-central Lithuania

Due to their close geographical proximity (~21 km as the crow flies) and archaeological similarities, the isotopic data of individuals from the cemeteries of Kalniškiai and Plinkaigalis will be discussed together and will be treated as one region, north-central Lithuania. From this region, out of 25 analysed samples (which represent 25 individuals), 23 yielded reliable stable isotope values. The investigated population (which included only individuals with reliable isotopic data) from this region is composed of 13 males (nine elites, two of middle ranks, and two commoners) and ten females (four elites and six commoners) (Table 2). The average $\delta^{13}C$ and $\delta^{15}N$ values of individuals from these two sites are -20.9±0.3‰ and 8.9±0.6‰, respectively. Overall, the isotopic data of all analysed humans from Kalniškiai and Plinkaigalis cemeteries suggest a relative similarity in dietary practices (Fig. 8), with no statistically significant isotopic distinctions detected between either different age or social groups (Appendices A.40, 41, 44–50, 53–59; B.40, 41, 44–50, 53–59). Overall, the isotopic data of humans from these two sites suggest a diet based primarily on terrestrial animal protein sources, with only one individual (elite female from Plinkaigalis burial 115 (no. 52)) showing an additional significant dietary input from freshwater fish (Fig. 8).

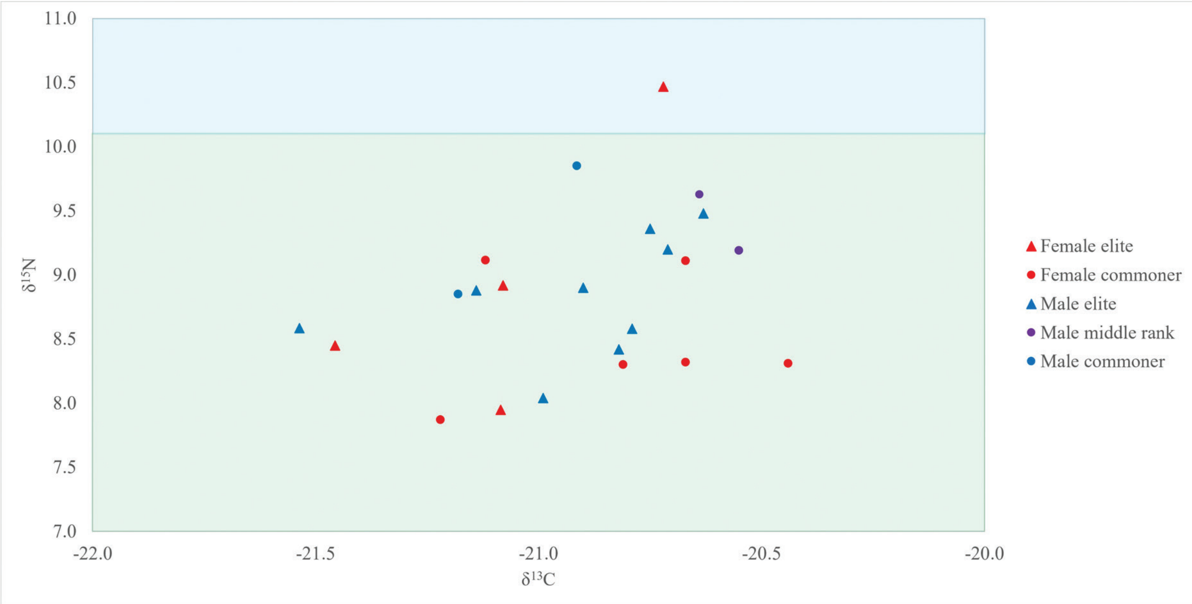

Figure 8. Scatter plot diagram of stable isotope values belonging to humans from north-central Lithuania (created by Simčenka).

In terms of sex, slight but statistically significant differences in values of nitrogen isotopic composition were determined to have been present between males and females, with the former having higher (9.0±0.5‰, n=13) $\delta^{15}N$ values compared to the latter (8.5±0.5‰, n=9; $p<0.05$; Appendix B.1, 2). However, it must be noted that this statistically significant difference was only determined when the clear outlier (elite female from Plinkaigalis burial 115 (no. 52) whose $\delta^{15}N$ value is 10.5‰) was excluded from the calculations (Appendices A.52; B.52). Overall, these isotopic differences between sexes suggest that males, on average, consumed slightly higher proportions of terrestrial animal and/or freshwater fish protein sources compared to females.

The most noticeable outlier from this Lithuanian region was the aforementioned elite female from Plinkaigalis burial 115 (no. 52) who had a significantly higher $\delta^{15}N$ value compared to other individuals from Plinkaigalis and Kalniškiai, which could indicate either higher proportions of terrestrial animal protein sources, a diet based primarily on freshwater fish protein sources, or a diet based on some combination of both terrestrial and aquatic protein sources (Table 2; Figs. 3 and 8). The inferred significantly different diet of this elite female could be related to the previously observed $^{87}Sr/^{86}Sr$ ratios in her tooth enamel sample, which suggested that this female was a non-locally born migrant whose potential provenance was a more radiogenic area abroad (unpublished data). Given her relatively young age (20–29 years, the age interval which roughly corresponds to the time of potential marriage) and the fact that her isotopically analysed bone element, the occipital bone, has one of the slowest bone turnover rates compared to other human bones (Fahy et al. 2017), it is possible that her $\delta^{13}C$ and $\delta^{15}N$ values reflect the consumed foods that originated from a territory outside of Plinkaigalis, which could correspond to her birthplace from which she at some point migrated to her new habitat near her burial place. Finally, it is worth pointing out that this female belonged to the uppermost part of the elite, as attested by her grave goods assemblage, which is the richest female set in the cemetery (Kazakevičius 1993, pp. 149–150). Her social standing could have guaranteed her access to a diet different from that common to the lower-rank females of the same community.

2.5 Diet in central Lithuania

The cemetery of Marvelė, according to its geographical position, was defined as representing the region of central Lithuania. From this region, out of 14 analysed samples (which represent 14 individuals), 13 yielded reliable stable isotope values. The investigated population (which included only individuals with reliable isotopic data) from this region is composed of eight males (four elites, three from middle ranks, and one commoner) and five females (three elites and two commoners) (Table 2). The average $\delta^{13}C$ and $\delta^{15}N$ values of individuals from this site are -20.3±0.2‰ and 9.8±0.5‰, respectively. These results suggest a mixed diet based on varying proportions of both freshwater fish and terrestrial animal protein sources (Figs. 3 and 9). No statistically significant isotopic differences were detected between males and females in terms of their $\delta^{13}C$ values ($p>0.05$; see Appendix A.64, 69, 70), however, there was a statistically significant difference in $\delta^{15}N$ values between them ($p<0.05$; see Appendix B.64,

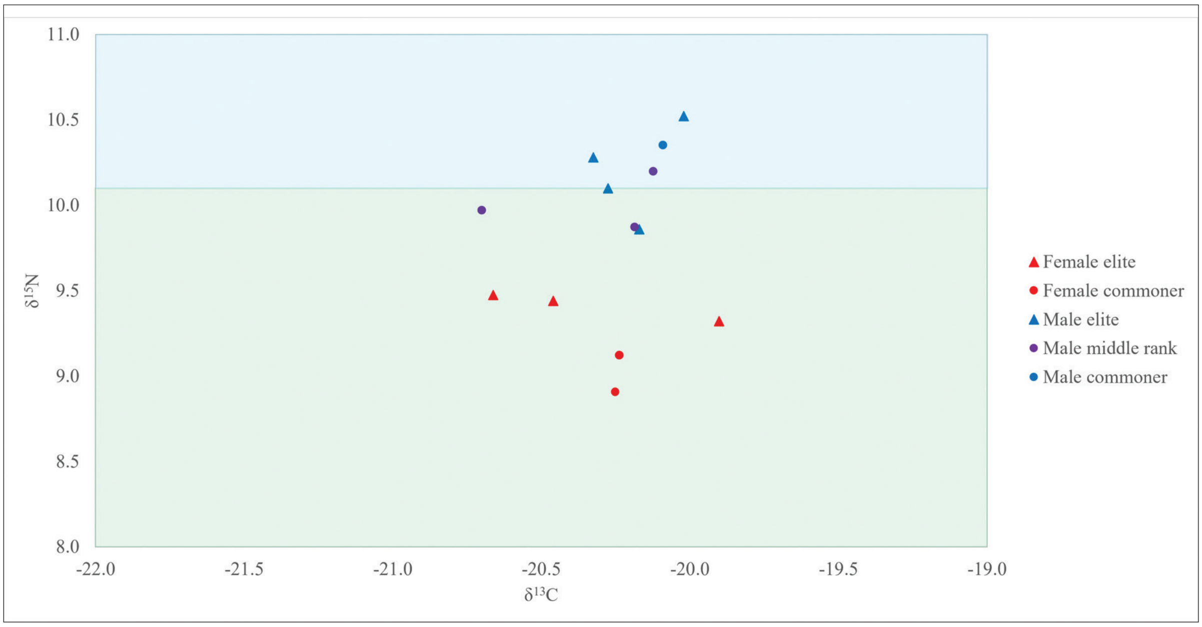

Figure 9. Scatter plot diagram of stable isotope values belonging to humans from central Lithuania (created by Simčenka).

69, 70). These isotopic differences may suggest a higher dietary contribution from freshwater fish and/or animal protein for males compared to females. No statistically significant isotopic differences were detected between either age or social groups when they include both males and females ($p>0.05$; Appendices A.66–68; B.66–68).

Overall, the isotopic data of humans from Marvelė cemetery suggest a diet which, compared to individuals from Kalniškiai and Plinkaigalis, contained much higher proportions of terrestrial animal and/or freshwater fish protein sources (Fig. 9). Specifically, the isotopic data of eight individuals were only seen within the terrestrial herbivore/omnivore protein group, whereas the stable isotope values of the remaining five individuals were observed in both terrestrial and freshwater groups (Fig. 9). This isotopically attested dietary distinction between central and north-central Lithuanian sites was confirmed by statistical analysis, which indicated statistically significant differences in both $\delta^{13}C$ and $\delta^{15}N$ values between both regions ($p<0.05$; Appendices A.19–21; B.19–21). One possible explanation for this result is the fact that Marvelė is located on the bank of the Nemunas River, the longest river in Lithuania (Fig. 1). This could have meant freshwater fish was a more available and therefore more frequently consumed food source, which resulted in higher $\delta^{13}C$ and, especially, $\delta^{15}N$ values in this site's population. Meanwhile, the sites of Kalniškiai and Plinkaigalis were both located near much smaller rivers (Dubysa and Šušvė, respectively), which might have meant fishing was not as sustainable for subsistence as in Marvelė. However, other factors that could have affected freshwater fish consumption (e.g. an individual's social status, health, personal dietary preferences etc.) cannot be ruled out at this juncture either.

Similarly, as was the case in Kalniškiai and Plinkaigalis, individuals from Marvelė showed significant isotopic differences on the basis of sex, with males on average having higher $\delta^{15}N$ values (10.1±0.2‰, n=8) compared to females (9.3±0.2‰, n=5; $p<0.05$; Appendix B.64, 69, 70). This finding indicates that in Marvelė, males on average consumed higher proportions of freshwater fish and/or terrestrial animal protein sources compared to females. This could suggest a more pronounced gender differentiation (at least in terms of consumed foods) in the central part of Lithuania during the Roman and Migration periods, although it cannot be discounted that the small sample sizes of the analysed human skeletal material from other Lithuanian regions could have been the reason why similar sex-based dietary differences were not detected.

2.6 Diet in western Lithuania

Due to their close geographical proximity (~16 km distance), and similarities in burial types and grave goods, the isotopic data of individuals from the cemeteries of Pagrybis and Vėluikiai will be discussed together and will be treated as one region — western Lithuania. From this region, out of 19 analysed samples (which represent 19 individuals), 18 yielded reliable stable isotope values. The investigated population (which included only individuals with reliable isotopic data) from this region is composed of ten males (two higher elites, six elites, and two commoners), one presumed male (elite) and seven females (four elites and three commoners) (Table 2). The average

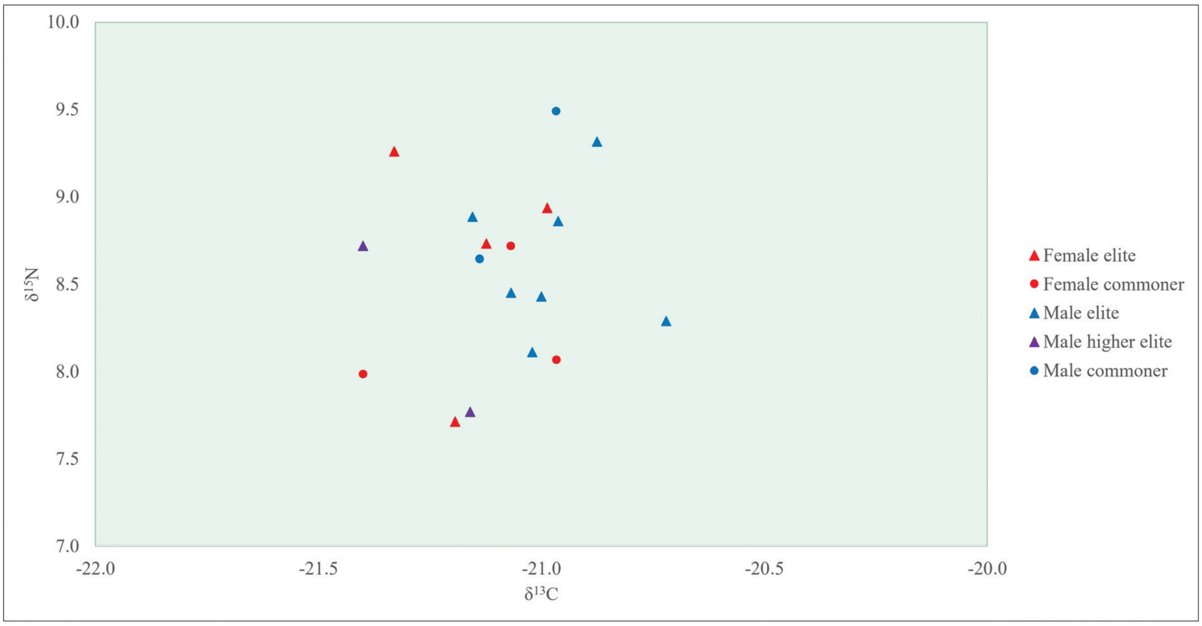

Figure 10. Scatter plot diagram of stable isotope values belonging to humans from western Lithuania (created by Edvardas Simčenka).

$\delta^{13}C$ and $\delta^{15}N$ values of individuals from these two sites are -21.1±0.2‰ and 8.6±0.5‰, respectively. No statistically significant isotopic differences were detected between sexes ($p>0.05$; Appendices A.71, 72, 78–81; B.71, 72, 78–81). These results suggest similar diets based mainly on terrestrial animal protein sources (Fig. 3). Similarly, no statistically significant isotopic differences were detected between either age or social groups ($p>0.05$; Appendices A.73–77, 82, 83; B.73–77, 82, 83).

In Pagrybis and Vėluikiai, all individuals, without any exception based on sex, age or social group ($p>0.05$; Appendices A.71–83; B.71–83), had isotopic values that indicate similar diets based primarily on terrestrial protein sources (Figs. 3 and 10). No significant input from freshwater fish protein sources were observed in any individual from western Lithuania, which could suggest that fishing had at best only played a supplementary dietary role, while agriculture, especially animal husbandry, was most likely the main subsistence strategy in this part of Lithuania during the periods in question.

Conclusions

In this study, the main goal was to investigate dietary patterns of humans who lived in various parts of Lithuania during the Late Roman–Migration period and somewhat later (ca. 200–700 AD) through stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope analysis of bone collagen samples. The results of this study suggest that, for the analysed humans, terrestrial animals were the most important protein source, although the exact proportion of them compared to other protein sources (such as freshwater fish) varied in each individual's diet.

The statistical analysis of the isotopic data suggests that there were statistically significant dietary differences between individuals who lived in different Lithuanian regions (as represented by specific sites or their groups) during the Late Roman and Migration periods. In eastern Lithuania, the majority of people subsisted primarily on terrestrial animal protein sources, while in the diets of the rest of the analysed individuals freshwater fish also played a substantial dietary role, along with faunal species. Individuals from Marvelė in central Lithuania, on average, had one of the highest $\delta^{15}N$ values, which might indicate a larger dietary protein contribution from terrestrial animals and/or freshwater fish than in any other site or region. Meanwhile, in other central Lithuanian sites (Kalniškiai and Plinkaigalis) humans had more terrestrial diets, with some individuals potentially consuming larger amounts of faunal and/or aquatic products. At the western Lithuanian sites of Pagrybis and Vėluikiai, individuals had somewhat similar diets to those of the Kalniškiai and Plinkaigalis populations, although, terrestrial animals seem to have been the only significant protein source for the people in this region, while the dietary input from freshwater fish was most likely negligible.

When considering the isotopic data of humans from all investigated sites together, males on average had higher $\delta^{15}N$ values compared to females, suggesting dietary differences related to greater dietary contributions from terrestrial animal and/or freshwater fish in the males' diet. The sex-based isotopic differences were also observed among individuals from Kalniškiai, Plinkaigalis and Marvelė, which combined comprise the majority of analysed human samples, which most likely caused this trend to be seen on the country scale as well. Unfortunately, due to the relatively small number of samples from other Lithuanian regions (especially eastern Lithuania), it is impossible to ascertain whether these sex-based isotopic/dietary differences were absent in other regions of Lithuania (as the current isotopic data suggests) or whether the small human sample size from those areas led to the failure to observe this trend.

Based on the stable isotope values of human bone collagen samples analysed in this study, it can be concluded that there were no isotopically distinguishable dietary differences between individuals of different social groups during the Late Roman and Migration periods in Lithuania. This could reflect either a relatively weak social differentiation, whereby elites and commoners had similar diets, or the possibility that separate social groups had in fact different diets but it was impossible to detect that due to potential isotopic similarities between different animal species that were consumed by the studied humans. The few possible exceptions to this trend could be seen in the case of male chieftains from Taurapilis 5/1 and Paduobė-Šaltaliūnė III 17/1, as well as the elite female from Plinkaigalis 115, whose significantly different (more negative $\delta^{13}C$ and, especially, higher $\delta^{15}N$) stable isotope values compared to those of all the rest of the analysed individuals might suggest a diet based on exceptionally high proportions of terrestrial animal and/or freshwater fish protein sources, which might have resulted from, among other potential reasons (like possible non-local origins), higher social status, as attested by grave goods.

Overall, these results have given us one of the first glimpses into the types of dietary habits of people in various parts of Lithuania during the Roman and Migration periods. Furthermore, the results of this study could also serve as a good starting point for future investigations into other dietary aspects in the territories and periods in question that remain unknown.

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Abbreviations

Archaeol. Baltica — Archaeologia Baltica

Arch. Lituana — Archaeologia Lituana

ATL — Archeologiniai tyrinėjimai Lietuvoje ... Vilnius

Hundred Years — G. Zabiela, Z. Baubonis, E. Marcinkevičiūtė eds. A Hundred Years of Archaeological Discoveries in Lithuania, Vilnius: Lithuanian Archaeology Society

Lietuvos Arch. — Lietuvos archeologija

Veget Hist Archaeobot — Vegetation History and Archaeobotany

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Vėlyvojo Romėniškojo ir Tautų kraustymosi laikotarpių (apie 200–700 m.) žmonių mityba stabiliųjų anglies ir azoto izotopų duomenimis

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Santrauka

Šio straipsnio tikslas – išanalizuoti Vėlyvuoju Romėniškuoju ir Tautų kraustymosi laikotarpiais Lietuvos teritorijoje gyvenusių žmonių mitybą, remiantis žmonių kaulų kolageno stabiliųjų izotopų (δ13C ir δ15N) analizės duomenimis. Ištirtas 71 kolageno mėginys iš Rytų, Šiaurės vidurio, Vidurio ir Vakarų Lietuvos laidojimo paminklų. Gauti izotopiniai rezultatai atskleidė, kad visų tirtų žmonių mityboje pagrindinį vaidmenį vaidino sausumos gyvūnų baltymai, tačiau jų santykinė dalis kitų baltymų šaltinių (ypač gėlavandenių žuvų) atžvilgiu skyrėsi.

Statistinė gautų izotopinių verčių analizė parodė buvus statistiškai reikšmingų mitybos skirtumų tarp žmonių, gyvenusių skirtinguose Lietuvos regionuose. Didžiosios dalies žmonių, gyvenusių Rytų Lietuvoje, pagrindinis baltymų šaltinis buvo sausumos gyvūnai, tuo tarpu likusių šio regiono individų svarbiausiais baltymų šaltiniais galėjo būti arba gyvūnai, arba gėlavandenės žuvys, arba tam tikras šių šaltinių derinys. Vidurio Lietuvos žmonės, lyginant su kitais regionais, turėjo vidutiniškai aukščiausias δ15N vertes, kurios gali rodyti, kad jų mityboje didžiausią santykinę baltymų dalį sudarė sausumos gyvūnai ir (arba) gėlavandenės žuvys. Tuo tarpu daugumos Šiaurės vidurio Lietuvos kapinynuose palaidotų žmonių mityboje, lyginant su Vidurio Lietuva, sausumos gyvūnai sudarė didesnę baltymų dalį nei gėlavandenės žuvys. Vakarų Lietuvos kapinynuose palaidotų individų mityba buvo panaši į Šiaurės vidurio Lietuvos, nors izotopiniai duomenys rodo dar didesnę santykinę sausumos gyvūnų ir mažesnę gėlavandenių žuvų baltymų dalį.

Vertinant visų tirtų Lietuvos regionų žmonių izotopų duomenis, buvo nustatyta, kad vyrų δ15N vertės buvo statistiškai reikšmingai aukštesnės nei moterų, kas rodo didesnę sausumos gyvūnų ir (arba) gėlavandenių žuvų dalį vyrų mityboje. Tačiau nagrinėjant mitybos skirtumus tarp lyčių kiekvieno išskirto regiono mastu, statistiškai reikšmingų vyrų ir moterų mitybos skirtumų nustatyta tik Šiaurės vidurio ir Vidurio Lietuvoje, tuo tarpu kituose tirtuose Lietuvos regionuose jų nepastebėta.

Remiantis šiame tyrime analizuotų žmonių kaulų kolageno mėginių stabiliųjų izotopų vertėmis ir pagal archeologinius kriterijus išskirtomis socialinėmis grupėmis, galima daryti išvadą, kad Vėlyvuoju Romėniškuoju ir Tautų kraustymosi laikotarpiais Lietuvoje nebuvo statistiškai reikšmingų mitybos skirtumų tarp skirtingo socialinio statuso asmenų. Tačiau taip pat negalima atmesti tikimybės, kad elito atstovų ir žemesnio socialinio statuso bendruomenės narių mityba iš tiesų skyrėsi, o baltymų pagrindą sudarė skirtingų rūšių gyvūnai, kurių tarpusavio stabiliųjų izotopų vertės buvo panašios.

Šio tyrimo rezultatai leido atlikti vieną iš pirmųjų bandymų įvertinti žmonių mitybos įpročius įvairiose Lietuvos vietovėse Vėlyvuoju Romėniškuoju ir Tautų kraustymosi laikotarpiais, o gauti izotopiniai duomenys gali padėti ateityje tiriant kitus, dar nežinomus, aptariamuoju laikotarpiu Lietuvoje gyvenusių žmonių mitybos aspektus.

Appendix A. Summary of statistical comparisons between δ^{13}C values of different human groups. For these statistical analyses. a parametric Student's t-test was used. In order to perform Student's t-test. at least 3 individuals had to represent each comparable group. The results of each statistical comparison follow a normal distribution ($p>0.05$). The p values of all comparison groups with statistically significant differences ($p<0.05$) are marked in bold. The numbers assigned to each statistical comparison (first column) will be used in the text to refer to specific comparison (e.g., Appendix A. 14).

No.	Comparison	Number of individuals in each group	Means	Ranges	Standard deviations (1σ)	p value
1	♂ vs ♀ (including probable, excluding presumed sexes)	39; 23	-20.8; -20.8	-22.0 – -20.0; -21.5 – -19.9	0.5; 0.4	0.891
2	♂ vs ♀ (excluding probable and presumed sexes)	33; 17	-20.8; -20.9	-22.0 – -20.0; -21.5 – -20.4	0.5; 0.3	0.475
3	all elites vs middle rank and commoners	41; 24	-20.9; -20.7	-22.0 – -19.9; -21.4 – -20.0	0.5; 0.4	0.079
4	all elites vs commoners	41; 19	-20.9; -20.8	-22.0 – -19.9; -21.4 – -20.0	0.5; 0.4	0.281
5	elites (excluding chieftains and higher ones) vs commoners	37; 19	-20.9; -20.8	-22.0 – -19.9; -21.4 – -20.0	0.5; 0.4	0.401
6	all elites vs middle rank	41; 5	-20.9; -20.4	-22.0 – -19.9; -20.7 – -20.1	0.5; 0.3	**0.035**
7	elites vs middle rank	37; 5	-20.9; -20.4	-22.0 – -19.9; -20.7 – -20.1	0.5; 0.3	0.051
8	middle rank vs commoners	5; 19	-20.4; -20.8	-20.7 – -20.1; -21.4 – -20.0	0.3; 0.4	0.110
9	non-adults vs all adults	3; 62	-20.6; -20.8	-21.0 – -19.9; -22.0 – -19.9	0.6; 0.4	0.466
10	any adults vs young. middle and old adults	21; 41	-20.7; -20.9	-21.9 – -19.9; -22.0 – -20.0	0.5; 0.4	**0.029**
11	young adults vs middle adults	15; 19	-21.1; -20.8	-22.0 – -20.6; -21.5 – -20.0	0.4; 0.5	0.105
12	young adults vs old adults	15; 7	-21.1; -20.9	-22.0 – -20.6; -21.1 – -20.4	0.4; 0.2	0.169
13	young adults vs any adults	15; 21	-21.1; -20.7	-22.0 – -20.6; -21.9 – -19.9	0.4; 0.5	**0.009**
14	middle adults vs old adults	19; 7	-20.8; -20.9	-21.5 – -20.0; -21.1 – -20.4	0.5; 0.2	0.913
15	middle adults vs any adults	19; 21	-20.8; -20.7	-21.5 – -20.0; -21.9 – -19.9	0.5; 0.5	0.265
16	old adults vs any adults	7; 21	-20.9; -20.7	-21.1 – -20.4; -21.9 – -19.9	0.2; 0.5	0.336
17	Taurapilis vs rest of Eastern Lithuania	3; 8	-21.8; -20.6	-22.0 – -20.4; -21.2 – -19.9	0.3; 0.4	**0.002**
18	Kalniškiai vs Plinkaigalis	10; 13	-21.0; -20.8	-21.5 – -20.6; -21.2 – -20.4	0.3; 0.2	0.099
19	Kalniškiai vs Marvelė	10; 13	-21.0; -20.3	-21.5 – -20.6; -20.7 – -19.9	0.3; 0.2	**<0.0001**
20	Plinkaigalis vs Marvelė	13; 13	-20.8; -20.3	-21.2 – -20.4; -20.7 – -19.9	0.2; 0.2	**<0.0001**
21	Kalniškiai and Plinkaigalis vs Marvelė	23; 13	-20.9; -20.3	-21.5 – -20.4; -20.7 – -19.9	0.3; 0.2	**<0.0001**
22	Pagrybis vs Vėluikiai	15; 3	-21.0; -21.3	-21.3 – -20.7; -21.4 – -21.1	0.1; 0.2	**0.023**
23	Eastern Lithuania (including Taurapilis) vs Central Lithuania (including Marvelė)	11; 36	-20.9; -20.7	-22.0 – -19.9; -21.5 – -19.9	0.7; 0.4	0.164
24	Eastern Lithuania (excluding Taurapilis) vs Central Lithuania (including Marvelė)	8; 36	-20.6; -20.7	-21.2 – -19.9; -21.5 – -19.9	0.4; 0.4	0.604
25	Eastern Lithuania (including Taurapilis) vs Central Lithuania (excluding Marvelė)	11; 23	-20.9; -20.9	-22.0 – -19.9; -21.5 – -20.4	0.7; 0.3	0.992
26	Eastern Lithuania (including Taurapilis) vs Marvelė	11; 13	-20.9; -20.3	-22.0 – -19.9; -20.7 – -19.9	0.7; 0.2	**0.004**

Appendix A. Continuation

No.	Comparison	Number of individuals in each group	Means	Ranges	Standard deviations (1σ)	p value
27	Eastern Lithuania (excluding Taurapilis) vs Marvelė	8; 13	-20.6; -20.3	-21.2 – -19.9; -20.7 – -19.9	0.4; 0.2	**0.037**
28	Eastern Lithuania (excluding Taurapilis) vs Central Lithuania (excluding Marvelė)	8; 23	-20.6; -20.9	-21.2 – -19.9; -21.5 – -20.4	0.4; 0.3	**0.026**
29	Taurapilis vs Central Lithuania (including Marvelė)	3; 36	-21.8; -20.7	-22.0 – -21.4; -21.5 – -19.9	0.3; 0.4	**<0.0001**
30	Taurapilis vs Central Lithuania (excluding Marvelė)	3; 23	-21.8; -20.9	-22.0 – -21.4; -21.5 – -20.4	0.3; 0.3	**<0.0001**
31	Taurapilis vs Marvelė	3; 13	-21.8; -20.3	-22.0 – -21.4; -20.7 – -19.9	0.3; 0.2	**<0.0001**
32	Eastern Lithuania (including Taurapilis) vs Western Lithuania	11; 18	-20.9; -21.1	-22.0 – -19.9; -21.4 – -20.7	0.7; 0.2	0.289
33	Eastern Lithuania (excluding Taurapilis) vs Western Lithuania	8; 18	-20.6; -21.1	-21.2 – -19.9; -21.4 – -20.7	0.4; 0.2	**0.000**
34	Taurapilis vs Western Lithuania	3; 18	-21.8; -21.1	-22.0 – -21.4; -21.4 – -20.7	0.3; 0.2	**<0.0001**
35	Central Lithuania (including Marvelė) vs Western Lithuania	36; 18	-20.7; -21.1	-21.5 – -19.9; -21.4 – -20.7	0.4; 0.2	**0.000**
36	Central Lithuania (excluding Marvelė) vs Western Lithuania	23; 18	-20.9; -21.1	-21.5 – -20.4; -21.4 – -20.7	0.3; 0.2	**0.024**
37	Marvelė vs Western Lithuania	13; 18	-20.3; -21.1	-20.7 – -19.9; -21.4 – -20.7	0.2; 0.2	**<0.0001**
38	all elites vs commoners in Eastern Lithuania	8; 3	-21.1; -20.5	-22.0 – -19.9; -21.0 – -20.0	0.7; 0.5	0.204
39	♂ (including probable) vs ♀ in Kalniškiai	6; 4	-21.0; -21.1	-21.5 – -20.6; -21.5 – -20.7	0.3; 0.3	0.617
40	elites vs commoners in Kalniškiai	6; 3	-21.1; -20.9	-21.5 – -20.7; -21.1 – -20.7	0.3; 0.2	0.291
41	young adults vs middle adults in Kalniškiai	4; 4	-21.1; -21.0	-21.5 – -20.6; -21.5 – -20.7	0.3; 0.4	0.775
42	♂ vs ♀ in Plinkaigalis	7; 6	-20.8; -20.8	-21.2 – -20.6; -21.2 – -20.4	0.2; 0.3	0.957
43	♂ vs ♀ (excluding ♀ from burial 115) in Plinkaigalis	7; 5	-20.8; -20.8	-21.2 – -20.6; -21.2 – -20.4	0.2; 0.3	0.855
44	elites vs commoners in Plinkaigalis	7; 5	-20.8; -20.9	-21.1 – -20.6; -21.2 – -20.4	0.2; 0.3	0.794
45	young adults vs middle adults in Plinkaigalis	3; 3	-20.9; -20.9	-21.1 – -20.7; -21.2 – -20.8	0.2; 0.2	0.773
46	young adults vs old adults in Plinkaigalis	3; 3	-20.9; -20.7	-21.1 – -20.7; -21.0 – -20.4	0.2; 0.3	0.447
47	young adults vs any adults in Plinkaigalis	3; 4	-20.9; -20.8	-21.1 – -20.7; -21.2 – -20.6	0.2; 0.3	0.773
48	middle adults vs old adults in Plinkaigalis	3; 3	-20.9; -20.7	-21.2 – -20.8; -21.0 – -20.4	0.2; 0.3	0.356
49	middle adults vs any adults in Plinkaigalis	3; 4	-20.9; -20.8	-21.2 – -20.8; -21.2 – -20.6	0.2; 0.3	0.608
50	old adults vs any adults in Plinkaigalis	3; 4	-20.7; -20.8	-21.0 – -20.4; -21.2 – -20.6	0.3; 0.3	0.663
51	♂ vs ♀in Kalniškiai and Plinkaigalis	13; 10	-20.9; -20.9	-21.5 – -20.6; -21.5 – -20.4	0.3; 0.3	0.755

Appendix A. Continuation

No.	Comparison	Number of individuals in each group	Means	Ranges	Standard deviations (1σ)	p value
52	♂ vs ♀ (excluding ♀ from burial 115) in Kalniškiai and Plinkaigalis	13; 9	-20.9; -20.9	-21.5 – -20.6; -21.5 – -20.4	0.3; 0.3	0.633
53	elites vs commoners in Kalniškiai and Plinkaigalis	13; 8	-21.0; -20.9	-21.5 – -20.6; -21.2 – -20.4	0.3; 0.3	0.478
54	young adults vs middle adults in Kalniškiai and Plinkaigalis	7; 7	-21.0; -21.0	-21.5 – -20.6; -21.5 – -20.7	0.3; 0.3	0.901
55	young adults vs old adults in Kalniškiai and Plinkaigalis	7; 5	-21.0; -20.8	-21.5 – -20.6; -21.1 – -20.4	0.3; 0.3	0.248
56	young adults vs any adults in Kalniškiai and Plinkaigalis	7; 4	-21.0; -20.8	-21.5 – -20.6; -21.2 – -20.6	0.3; 0.3	0.338
57	middle adults vs old adults in Kalniškiai and Plinkaigalis	7; 5	-21.0; -20.8	-21.5 – -20.7; -21.1 – -20.4	0.3; 0.3	0.306
58	middle adults vs any adults in Kalniškiai and Plinkaigalis	7; 4	-21.0; -20.8	-21.5 – -20.7; -21.2 – -20.6	0.3; 0.3	0.401
59	old adults vs any adults in Kalniškiai and Plinkaigalis	5; 4	-20.8; -20.8	-21.1 – -20.4; -21.2 – -20.6	0.3; 0.3	0.932
60	♂ elites vs ♀ elites in Kalniškiai and Plinkaigalis	9; 4	-20.9; -21.1	-21.5 – -20.6; -21.5 – -20.7	0.3; 0.3	0.350
61	♂ elites vs ♀ commoners in Kalniškiai and Plinkaigalis	9; 6	-20.9; -20.8	-21.5 – -20.6; -21.2 – -20.4	0.3; 0.3	0.530
62	♂ elites vs ♀commoners in Kalniškiai and Plinkaigalis	4; 6	-21.1; -20.8	-21.5 – -20.7; -21.2 – -20.4	0.3; 0.3	0.207
63	young adult ♂ vs young adult ♀ in Kalniškiai and Plinkaigalis	3; 4	-20.9; -21.1	-21.1 – -20.6; -21.5 – -20.7	0.3; 0.3	0.339
64	♂ vs ♀ in Marvelė	8; 5	-20.2; -20.3	-20.7 – -20.0; -20.7 – -19.9	0.2; 0.3	0.640
65	elites vs middle ranks in Marvelė	7; 3	-20.3; -20.3	-20.7 – -19.9; -20.7 – -20.1	0.3; 0.3	0.696
66	elites vs commoners in Marvelė	7; 3	-20.3; -20.2	-20.7 – -19.9; -20.3 – -20.1	0.3; 0.1	0.682
67	middle ranks vs commoners in Marvelė	3; 3	-20.3; -20.2	-20.7 – -20.1; -20.3 – -20.1	0.3; 0.1	0.492
68	middle adults vs any adults in Marvelė	5; 8	-20.2; -20.3	-20.5 – -20.0; -20.7 – -19.9	0.2; 0.3	0.573
69	♂ elites vs ♀elites in Marvelė	4; 3	-20.2; -20.3	-20.3 – -20.0; -20.7 – -19.9	0.1; 0.4	0.518
70	any adult ♂ vs any adult ♀ in Marvelė	4; 4	-20.3; -20.3	-20.7 – -20.1; -20.7 – -19.9	0.3; 0.3	0.785
71	♂ vs ♀(excluding probable ones) in Western Lithuania	9; 5	-21.1; -21.1	-21.4 – -20.7; -21.4 – -21.0	0.2; 0.2	0.573
72	♂ vs ♀ (including probable ones) in Western Lithuania	10; 7	-21.0; -21.2	-21.4 – -20.7; -21.4 – -21.0	0.2; 0.2	0.237
73	elites (excluding higher ones) vs commoners in Western Lithuania	11; 5	-21.0; -21.1	-21.3 – -20.7; -21.4 – -21.0	0.2; 0.2	0.467
74	all elites vs commoners in Western Lithuania	13; 5	-21.1; -21.1	-21.4 – -20.7; -21.4 – -21.0	0.2; 0.2	0.749
75	young adults vs middle adults in Western Lithuania	5; 6	-21.2; -21.1	-21.4 – -21.0; –21.4 – -20.7	0.2; 0.2	0.416
76	young adults vs any adults in Western Lithuania	5; 4	-21.2; -21.0	-21.4 – -21.0; –21.1 – -20.9	0.2; 0.1	0.076
77	middle adults vs any adults in Western Lithuania	6; 4	-21.1; -21.0	-21.4 – -20.7; –21.1 – -20.9	0.2; 0.1	0.444

Appendix A. Continuation

No.	Comparison	Number of individuals in each group	Means	Ranges	Standard deviations (1σ)	p value
78	♂ elites (excluding higher ones) vs ♀ elites in Western Lithuania	6; 4	-21.0; -21.2	-21.2 – -20.7; –21.3 – -21.0	0.2; 0.1	0.077
79	all ♂ elites vs ♀ elites in Western Lithuania	8; 4	-21.0; -21.2	-21.4 – -20.7; –21.3 – -21.0	0.2; 0.1	0.339
80	♂ elites (excluding higher ones) vs ♀ commoners in Western Lithuania	6; 3	-21.0; -21.1	-21.2 – -20.7; –21.4 – -21.0	0.2; 0.2	0.191
81	all ♂ elites vs ♀ commoners in Western Lithuania	8; 3	-21.0; -21.1	-21.4 – -20.7; –21.4 – -21.0	0.2; 0.2	0.493
82	♀ elites vs ♀ commoners in Western Lithuania	4; 3	-21.2; -21.1	-21.3 – -21.0; –21.4 – -21.0	0.1; 0.2	0.922
83	middle adult ♂ vs any adult ♂ in Western Lithuania	5; 3	-21.1; -20.9	-21.4 – -20.7; –21.0 – -20.9	0.2; 0.1	0.301

Appendix B. Summary of statistical comparisons between $\delta^{15}N$ values of different human groups. For these statistical analyses. a parametric Student's t-test was used. In order to perform Student's t-test. at least 3 individuals had to represent each comparable group. The results of each statistical comparison follow a normal distribution ($p>0.05$). The p values of all comparison groups with statistically significant differences ($p<0.05$) are marked in bold. The numbers assigned to each statistical comparison (first column) will be used in the text to refer to specific comparison (e.g., Appendix B.14).

No.	Comparison	Number of individuals in each group	Means	Ranges	Standard deviations (1σ)	p value
1	♂ vs ♀ (including probable. excluding presumed sexes)	39; 23	9.4; 8.8	7.8–10.9; 7.7–10.5	0.8; 0.7	**0.004**
2	♂ vs ♀ (excluding presumed sexes; all sites)	33; 17	9.3; 8.7	7.8–10.9; 7.7–10.5	0.8; 0.7	**0.007**
3	all elites vs middle rank and commoners	41; 24	9.2; 9.1	7.7–10.9; 7.9–10.4	0.8; 0.8	0.911
4	all elites vs commoners	41; 19	9.2; 9.0	7.7–10.9; 7.9–10.4	0.8; 0.7	0.379
5	elites (excluding chieftains and higher ones) vs commoners	37; 19	9.1; 9.0	7.7–10.5; 7.9–10.4	0.7; 0.7	0.430
6	all elites vs middle rank	41; 5	9.2; 9.8	7.7–10.9; 9.2–10.2	0.8; 0.4	0.095
7	elites vs middle rank	37; 5	9.1; 9.8	7.7–10.5; 9.2–10.2	0.7; 0.4	0.058
8	middle rank vs commoners	5; 19	9.8; 9.0	9.2–10.2; 7.9–10.4	0.4; 0.7	**0.028**
9	non–adults vs all adults	3; 62	9.1; 9.1	8.1–9.8; 7.7–10.9	0.9; 0.8	0.868
10	any adults vs young. middle and old adults	21; 41	9.4; 9.0	7.9–10.4; 7.7–10.9	0.7; 0.8	0.096
11	young adults vs middle adults	15; 19	9.0; 9.1	7.7–10.5; 7.8–10.9	0.8; 0.9	0.552
12	young adults vs old adults	15; 7	9.0; 8.9	7.7–10.5; 8.0–9.5	0.8; 0.5	0.748
13	young adults vs any adults	15; 21	9.0; 9.4	7.7–10.5; 7.9–10.4	0.8; 0.7	0.112
14	middle adults vs old adults	19; 7	9.1; 8.9	7.8–10.9; 8.0–9.5	0.9; 0.5	0.430
15	middle adults vs any adults	19; 21	9.1; 9.4	7.8–10.9; 7.9–10.4	0.9; 0.7	0.358
16	old adults vs any adults	7; 21	8.9; 9.4	8.0–9.5; 7.9–10.4	0.5; 0.7	0.081
17	Taurapilis vs rest of Eastern Lithuania	3; 8	9.9; 9.9	9.4–10.9; 9.3–10.3	0.8; 0.4	0.845
18	Kalniškiai vs Plinkaigalis	10; 13	8.9; 8.8	7.9–9.9; 7.9–10.5	0.6; 0.7	0.861
19	Kalniškiai vs Marvelė	10; 13	8.9; 9.8	7.9–9.9; 8.9–10.5	0.6; 0.5	**0.001**
20	Plinkaigalis vs Marvelė	13; 13	8.8; 9.8	7.9–10.5; 8.9–10.5	0.7; 0.5	**0.001**

Appendix B. Continuation

No.	Comparison	Number of individuals in each group	Means	Ranges	Standard deviations (1σ)	p value
21	Kalniškiai and Plinkaigalis vs Marvelė	23; 13	8.9; 9.8	7.9–10.5; 8.9–10.5	0.6; 0.5	**<0.0001**
22	Pagrybis vs Vėluikiai	15; 3	8.6; 8.4	7.7–9.5; 8.0–8.7	0.5; 0.4	0.500
23	Eastern Lithuania (including Taurapilis) vs Central Lithuania (including Marvelė)	11; 36	9.9; 9.2	9.3–10.9; 7.9–10.5	0.5; 0.7	**0.007**
24	Eastern Lithuania (excluding Taurapilis) vs Central Lithuania (including Marvelė)	8; 36	9.9; 9.2	9.3–10.3; 7.9–10.5	0.4; 0.7	**0.020**
25	Eastern Lithuania (including Taurapilis) vs Central Lithuania (excluding Marvelė)	11; 23	9.9; 8.9	9.3–10.9; 7.9–10.5	0.5; 0.6	**<0.0001**
26	Eastern Lithuania (including Taurapilis) vs Marvelė	11; 13	9.9; 9.8	9.3–10.9; 8.9–10.5	0.5; 0.5	0.710
27	Eastern Lithuania (excluding Taurapilis) vs Marvelė	8; 13	9.9; 9.8	9.3–10.3; 8.9–10.5	0.4; 0.5	0.783
28	Eastern Lithuania (excluding Taurapilis) vs Central Lithuania (excluding Marvelė)	8; 23	9.9; 8.9	9.3–10.3; 7.9–10.5	0.4; 0.6	**0.000**
29	Taurapilis vs Central Lithuania (including Marvelė)	3; 36	9.9; 9.2	9.4–10.9; 7.9–10.5	0.8; 0.7	0.115
30	Taurapilis vs Central Lithuania (excluding Marvelė)	3; 23	9.9; 8.9	9.4–10.9; 7.9–10.5	0.8; 0.6	**0.015**
31	Taurapilis vs Marvelė	3; 13	9.9; 9.8	9.4–10.9; 8.9–10.5	0.8; 0.5	0.729
32	Eastern Lithuania (including Taurapilis) vs Western Lithuania	11; 18	9.9; 8.6	9.3–10.9; 7.7–9.5	0.5; 0.5	**<0.0001**
33	Eastern Lithuania (excluding Taurapilis) vs Western Lithuania	8; 18	9.9; 8.6	9.3–10.3; 7.7–9.5	0.4; 0.5	**<0.0001**
34	Taurapilis vs Western Lithuania	3; 18	9.9; 8.6	9.4–10.9; 7.7–9.5	0.8; 0.5	**0.001**
35	Central Lithuania (including Marvelė) vs Western Lithuania	36; 18	9.2; 8.6	7.9–10.5; 7.7–9.5	0.7; 0.5	**0.003**
36	Central Lithuania (excluding Marvelė) vs Western Lithuania	23; 18	8.9; 8.6	7.9–10.5; 7.7–9.5	0.6; 0.5	0.136
37	Marvelė vs Western Lithuania	13; 18	9.8; 8.6	8.9–10.5; 7.7–9.5	0.5; 0.5	**<0.0001**
38	elites (all) vs commoners in e lithuania	8; 3	9.9; 9.7	9.4–10.9; 9.3–10.3	0.5; 0.5	0.587
39	♂ vs ♀ in Kalniškiai	6; 4	9.2; 8.5	8.6–9.9; 7.9–9.1	0.5; 0.5	0.052
40	elites vs commoners in Kalniškiai	6; 3	8.7; 9.1	7.9–9.2; 8.3–9.9	0.4; 0.8	0.302
41	young adults vs middle adults in Kalniškiai	4; 4	8.7; 8.9	7.9–9.6; 8.3–9.9	0.7; 0.7	0.714
42	♂ vs ♀ in Plinkaigalis	7; 6	8.8; 8.8	8.0–9.5; 7.9–10.5	0.5; 0.9	0.970
43	♂ vs ♀(without ♀ from burial 115) in Plinkaigalis	7; 5	8.8; 8.5	8.0–9.5; 7.9–9.1	0.5; 0.5	0.286
44	elites vs commoners in Plinkaigalis	7; 5	9.0; 8.5	8.0–10.5; 7.9–9.1	0.8; 0.5	0.210
45	young adults vs middle adults in Plinkaigalis	3; 3	9.3; 8.9	8.6–10.5; 8.4–9.4	1.0; 0.5	0.525
46	young adults vs old adults in Plinkaigalis	3; 3	9.3; 8.5	8.6–10.5; 8.0–9.1	1.0; 0.6	0.276
47	young adults vs any adults in Plinkaigalis	3; 4	9.3; 8.7	8.6–10.5; 7.9–9.5	1.0; 0.8	0.395
48	middle adults vs old adults in Plinkaigalis	3; 3	8.9; 8.5	8.4–9.4; 8.0–9.1	0.5; 0.6	0.406

Appendix B. Continuation

No.	Comparison	Number of individuals in each group	Means	Ranges	Standard deviations (1σ)	p value
49	middle adults vs any adults in Plinkaigalis	3; 4	8.9; 8.7	8.4–9.4; 7.9–9.5	0.5; 0.8	0.752
50	old adults vs any adults in Plinkaigalis	3; 4	8.5; 8.7	8.0–9.1; 7.9–9.5	0.6; 0.8	0.685
51	♂ vs ♀ in Kalniškiai and Plinkaigalis	13; 10	9.0; 8.7	8.0–9.9; 7.9–10.5	0.5; 0.8	0.251
52	♂ vs ♀ (without ♀ from burial 115) in Kalniškiai and Plinkaigalis	13; 9	9.0; 8.5	8.0–9.9; 7.9–9.1	0.5; 0.5	**0.027**
53	elites vs commoners in Kalniškiai and Plinkaigalis	13; 8	8.9; 8.7	7.9–10.5; 7.9–9.9	0.7; 0.6	0.621
54	young adults vs middle adults in Kalniškiai and Plinkaigalis	7; 7	9.0; 8.9	7.9–10.5; 8.3–9.9	0.8; 0.5	0.826
55	young adults vs old adults in Kalniškiai and Plinkaigalis	7; 5	9.0; 8.8	7.9–10.5; 8.0–9.2	0.8; 0.5	0.607
56	young adults vs any adults in Kalniškiai and Plinkaigalis	7; 4	9.0; 8.7	7.9–10.5; 7.9–9.5	0.8; 0.8	0.604
57	middle adults vs old adults in Kalniškiai and Plinkaigalis	7; 5	8.9; 8.8	8.3–9.9; 8.0–9.2	0.5; 0.5	0.663
58	middle adults vs any adults in Kalniškiai and Plinkaigalis	7; 4	8.9; 8.7	8.3–9.9; 7.9–9.5	0.5; 0.8	0.642
59	old adults vs any adults in Kalniškiai and Plinkaigalis	5; 4	8.8; 8.7	8.0–9.2; 7.9–9.5	0.5; 0.8	0.919
60	♂ elites vs ♀ elites in Kalniškiai and Plinkaigalis	9; 4	8.8; 8.9	8.0–9.5; 7.9–10.5	0.5; 1.1	0.780
61	♂ elites vs ♀commoners in Kalniškiai and Plinkaigalis	9; 6	8.8; 8.5	8.0–9.5; 7.9–9.1	0.5; 0.5	0.225
62	♂ elites vs ♀ commoners in Kalniškiai and Plinkaigalis	4; 6	8.9; 8.5	7.9–10.5; 7.9–9.1	1.1; 0.5	0.403
63	young adult ♂ vs young adult ♀ in Kalniškiai and Plinkaigalis	3; 4	9.0; 8.9	8.6–9.6; 7.9–10.5	0.5; 1.1	0.910
64	♂ vs ♀in Marvelė	8; 5	10.1; 9.3	9.9–10.5; 8.9–9.5	0.2; 0.2	<0.0001
65	elites vs middle ranks in Marvelė	7; 3	9.9; 10.0	9.3–10.5; 9.9–10.2	0.5; 0.2	0.597
66	elites vs commoners in Marvelė	7; 3	9.9; 9.5	9.3–10.5; 8.9–10.4	0.5; 0.8	0.334
67	middle ranks vs commoners in Marvelė	3; 3	10.0; 9.5	9.9–10.2; 8.9–10.4	0.2; 0.8	0.296
68	middle adults vs any adults in Marvelė	5; 8	10.0; 9.7	9.4–10.5; 8.9–10.4	0.4; 0.5	0.219
69	♂ elites vs ♀ elites in Marvelė	4; 3	10.2; 9.4	9.9–10.5; 9.3–9.5	0.3; 0.1	0.006
70	any adult ♂ vs any adult ♀ in Marvelė	4; 4	10.1; 9.2	9.9–10.4; 8.9–9.5	0.2; 0.2	0.002
71	♂ vs ♀(excluding probable ones) in Western Lithuania	9; 5	8.6; 8.3	7.8–9.5; 7.7–8.9	0.5; 0.5	0.247
72	♂ vs ♀(including probable ones) in Western Lithuania	10; 7	8.7; 8.5	7.8–9.5; 7.7–9.3	0.5; 0.6	0.457
73	elites (excluding higher ones) vs commoners in Western Lithuania	11; 5	8.6; 8.6	7.7–9.3; 8.0–9.5	0.5; 0.6	0.849
74	elites (including higher ones) vs commoners in Western Lithuania	13; 5	8.6; 8.6	7.7–9.3; 8.0–9.5	0.5; 0.6	0.986
75	young adults vs middle adults in Western Lithuania	5; 6	8.5; 8.4	7.7–9.3; 7.8–8.9	0.6; 0.4	0.826
76	young adults vs any adults in Western Lithuania	5; 4	8.5; 8.8	7.7–9.3; 8.4–9.3	0.6; 0.4	0.348
77	middle adults vs any adults in Western Lithuania	6; 4	8.4; 8.8	7.8–8.9; 8.4–9.3	0.4; 0.4	0.134

Appendix B. Continuation

No.	Comparison	Number of individuals in each group	Means	Ranges	Standard deviations (1σ)	p value
78	♂ elites (excluding higher ones) vs ♀ elites in Western Lithuania	6; 4	8.7; 8.7	8.3–9.3; 7.7–9.3	0.4; 0.7	0.895
79	♂ elites (including higher ones) vs ♀ elites in Western Lithuania	8; 4	8.6; 8.7	7.8–9.3; 7.7–9.3	0.5; 0.7	0.834
80	♂ elites (excluding higher ones) vs ♀ commoners in Western Lithuania	6; 3	8.7; 8.3	8.3–9.3; 8.0–8.7	0.4; 0.4	0.147
81	♂ elites (including higher ones) vs ♀ commoners in Western Lithuania	8; 3	8.6; 8.3	7.8–9.3; 8.0–8.7	0.5; 0.4	0.303
82	♀ elites vs ♀ commoners in Western Lithuania	4; 3	8.7; 8.3	7.7–9.3; 8.0–8.7	0.7; 0.4	0.400
83	middle adult ♂ vs any adult ♂ in Western Lithuania	5; 3	8.5; 8.9	7.8–8.9; 8.4–9.3	0.4; 0.4	0.256