Elīna Pētersone-Gordina[1] (https://orcid.org/0000-0001-6397-0897), Guntis Gerhards[1] (https://orcid.org/0000-0002-3347-7775), Antonija Vilcāne[1] (https://orcid.org/0000-0001-7492-1919), Andrew Millard[2] (https://orcid.org/0000-0002-8290-7428), Joanna Moore[2] (https://orcid.org/0000-0003-3918-4583)

THE FIRST DIETARY STABLE ISOTOPE DATA FROM THE ČUNKĀNI-DREŅĢERI IRON AGE POPULATION (SEVENTH – ELEVENTH CENTURIES CE) FROM LATVIA

[1]Institute of Latvian History, University of Latvia, Riga, Latvia

[2] Department of Archaeology, Durham University, Durham, UK

Corresponding author: Elīna Pētersone-Gordina, elina.petersone-gordina@lu.lv

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ABSTRACT

The main aim of this research was to study diet and possible social stratification in the Iron Age population of Čunkāni-Dreņģeri from Latvia through burial practice and dietary isotope analysis. This research also used previously published comparative dietary isotope data from archaeological populations in Latvia of various periods of time, not only Iron Age, to see if and how Iron Age populations were different.

Carbon and nitrogen dietary isotope analysis showed that the diet for all groups and individuals (N=29) at Čunkāni-Dreņģeri was largely homogenous, regardless of their gender, or social status as expressed by grave goods. Archaeological evidence for increased social stratification in this population occurs from the 10^{th} – 11^{th} centuries CE, probably in response to changes in trade. Isotopically the Čunkāni-Dreņģeri population was different than the contemporary comparative population from Latvia, indicative of differential subsistence strategies. The mean δ^{15}N value in the Čunkāni-Dreņģeri population was the lowest yet observed in Latvia, and the lowest among other archaeological populations from the wider region used in this study, which might be indicative of reliance on animal protein sources with lower δ^{15}N values, or lower local δ^{15}N baseline compared to other regions.

1. INTRODUCTION

This research is based on the Čunkāni-Dreņģeri Iron Age cemetery population from Latvia (7^{th} – 11^{th} centuries CE, latitude: 56.4192(56° 25' 09"), longitude: 24.2132(24° 12' 47"), Fig. 1). The main aim was to study diet in this population and establish if there were differences between gender groups.

In this study, although biological sex will be estimated for adult individuals using established osteological methods, gender (male and female, as estimated from grave goods) will be used in all discussions in order to include both adults and non-adults. This strategy does not suggest that there were only two gender categories in the Čunkāni-Dreņģeri population, as gender might have been a more complex concept (Arnold 2006: 138–140; Moen 2019). Likewise, gender as expressed by grave goods might not always correspond to biological sex, although a high degree of correlation has been reported from Danish Iron Age burials (Sellevold et al. 1984). A recent pilot study comparing gender and biological sex as determined by ancient DNA and amelogenin peptide analyses in non-adult individuals from Iron Age cemeteries in Latvia (N=17) also showed complete correlation and demonstrated potential for future research on a larger scale (Ķimsis et al. 2023). Gender differences in the Čunkāni-Dreņģeri cemetery might have been expressed through particular grave goods. Grave goods associated with male gender burials in the Semigallian culture were dominated by weapons and included spearheads, battle knives, narrow bladed axes, sometimes horse-riding equipment, drinking horns, and very rarely, a sword. Female gender burials often included tools such as a hoe, a sickle, and an awl. Individuals of both genders were given jewellery items including bronze neck rings, decorative pins, bracelets, brooches, belts, and clothing with bronze decorations (Atgāzis 1994a, 25). For non-adults, the jewellery items were similar, but smaller in size, and no battle weaponry was given, except on rare occasions, miniature versions of battle knives and axes (Atgāzis 1994a, 24 – 26).

It was also possible to explore dietary differences between people of differential social status, as expressed by grave goods, but only on an individual, rather than population, level. The second half of the Middle Iron Age (7th – 9th century CE), and the Late Iron Age in Latvia (9th – 12th centuries CE) (Vasks, 2018: 28 - 38), partly coincide with the Merovingian period in western and central Europe (550-800 CE), and Viking Age in Northern Europe (CE 750 - 1050, Brink and Price 2008). Archaeological evidence suggests that Baltic ethnic groups who lived in the territory of modern-day Latvia, had access to international trade links during the Viking Age (Vasks 2018), which could have also introduced cultural influence from the wider region.

So far, Iron Age populations in Latvia have not been studied in detail, although a number have been excavated in the last 150 years (Vasks 2016). The Čunkāni-Dreņģeri population is only the second from Iron Age Latvia to be subjected to dietary isotope (carbon and nitrogen) analysis, the first being the Latgallian Lejasbitēni population (Fig. 1). Dietary analysis of the Lejasbitēni population revealed significant differences in terms of the proportion and/or source of animal protein in childhood diet between people of male and female gender (Fig. 4). These differences were consistent with changes in burial ritual with the advance of the Viking Age from the 9th century CE onwards (Pētersone-Gordina et al. 2022). Considering that the Čunkāni-Dreņģeri cemetery is largely contemporaneous with Lejasbitēni, our hypothesis was that archaeological and dietary analysis of the Čunkāni-Dreņģeri population would reveal similar trends.

We also hypothesised that individuals with higher social status had diet richer in animal protein, although no correlation was found between childhood diet and adult status in the Lejasbitēni population, probably due to a small sample size (Pētersone-Gordina et al. 2022).

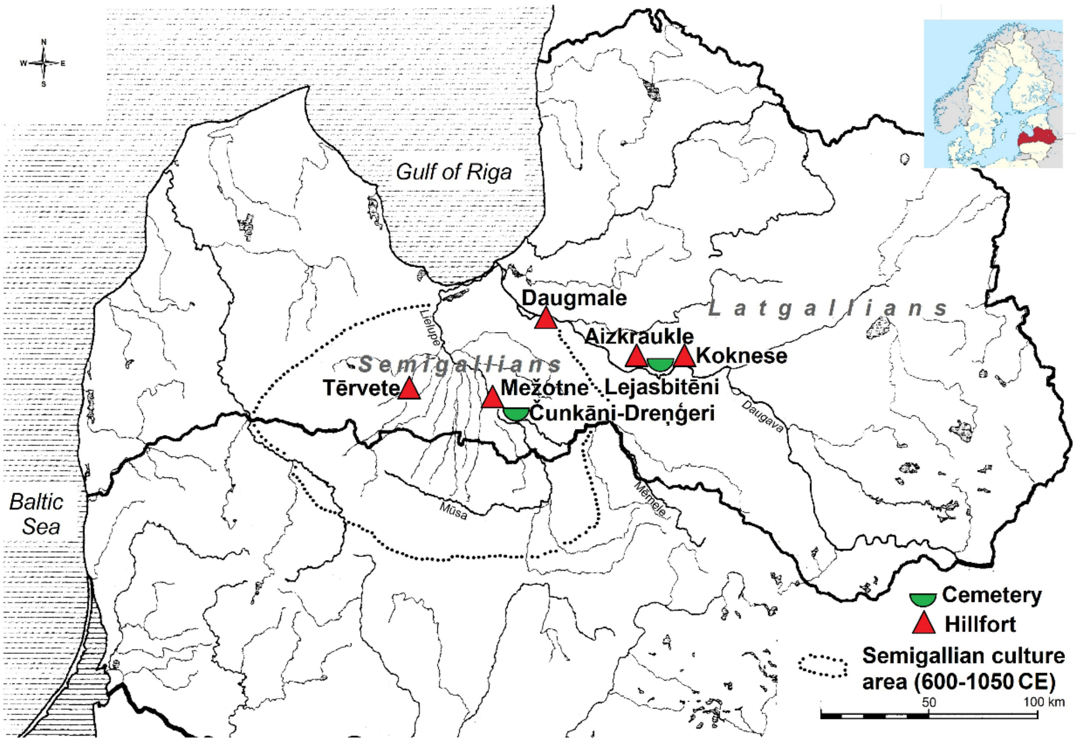

Fig. 1 Map of Latvia showing the Semigallian cultural area during the Iron Age (CE 600-1050) (Vaškevičiūtė 2004, Fig. 1), the Iron Age cemeteries of Čunkāni-Dreņģeri and Lejasbitēni, and the sites with comparative faunal data used in this study. The map in the upper right corner shows the geographic location of Latvia.

In the study of Iron Age populations from Latvia, grave goods have also traditionally been used to interpret the social status of an individual, applying qualitative and quantitative methods of analysis (Šnē 2002, 247 – 274; Radiņš 1999, 131 – 133). In Semigallian male gender burials from the 8th – 9th centuries CE, the number of spearheads might have been linked to their social status. It is common to find two spearheads, while one is less common, but three to five are very rare. One spearhead might have been linked to young or old age or point to low social status of the individual. In contrast, the presence of five spearheads might have represented high social status, material wealth, or military success (Atgāzis 1994a, 25). Three and more spearheads have been found in several 7th – 9th century Semigallian cemeteries, including in the territory of modern Lithuania (Atgāzis 1994b, 36). In the Čunkāni-Dreņģeri cemetery, 66.3% of male gender burials (N=57) had one spearhead, while 24.4% of burials (N=21) had two, 5.8% (N=5) had three, but five spearheads were only present in 3.6% of male gender burials (N=3).

1.1 The use of carbon and nitrogen isotope analysis in studying the Čunkāni-Dreņģeri cemetery population

A small proportion of the burials from this cemetery were subjected to carbon and nitrogen stable isotope analysis. The main objective of dietary isotope analysis in this population was to find out if there were intra-cemetery differences between people of different age, gender, and social status, as expressed by grave goods, and if this population was isotopically different from other cemetery populations in Latvia. The basic principles of this analysis are explained below. This research will also provide much needed comparative Baltic Iron Age dietary isotope data, because to date, few such data have been published (Bliujienė et al. 2020, Cocozza et al. 2022, Etu-Sihvola et al. 2019, Simčenka et al. 2022), resulting in a regional gap in knowledge.

Carbon stable isotope ($\delta^{13}C$) analysis is mainly used in archaeological studies to distinguish between C_3 plant-based terrestrial diets, C_4 plant-based terrestrial, or marine diets, or a mix of these (Ambrose and Norr 1993). For fully terrestrial human diets with the inclusion of animal protein the main signature is provided by the fauna (Fernandes et al. 2012) and will depend on whether the animals feed on plants with different photosynthetic pathways (C_3 and C_4), rather than from humans directly consuming these plant resources. $\delta^{13}C$ values of marine resources overlap with those of C_4 plants, which are between -5.0 ‰ and -17.0 ‰ (Ambrose and Norr 1993). One type of C_4 crop, millet, was widely grown in Eastern Europe since the 2nd millennium BCE (Filipović et al. 2020), where it has yielded $\delta^{13}C$ values between –11 ‰ and -9 ‰ (Antanaitis and Ogrinc 2000; Filipović et al. 2020; Mueller-Bieniek et al. 2019). In Latvia, the oldest site with evidence for millet found so far is the late Bronze Age - early Iron Age Ķivutkalns hillfort (Fig. 7), and its possible use in diet has been reported from two Bronze Age and early Iron Age cemetery populations in Latvia (Vasks and Zariņa 2014, Legzdiņa et al. 2020). Most archaeological evidence for millet from Latvian sites was found in the late Iron Age layers in the Tērvete and Koknese hillforts (Rasiņš and Tauriņa 1983, 154, Fig. 1).

In the brackish waters of the Baltic Sea, $\delta^{13}C$ values can be lower than in the ocean, resulting in lower values for the animals and humans consuming these resources. For example, at the Neolithic Västerbjers site on the island of Gotland, Sweden, the mean value of the human population, which was highly dependent on Baltic Sea seals, was -14.8 ±0.6 ‰ (Eriksson 2004), while in Later Viking Age and Early Christian populations from the island, with an estimated 50% marine dietary contribution, the mean $\delta^{13}C$ value was -17.3±1.2 ‰ (Kosiba et al. 2007).

The detection of freshwater resources using carbon stable isotope analysis can be challenging. The global average $\delta^{13}C$ value of freshwater resources has traditionally been accepted to be close to those of C_3 plants, around -27.0 ‰ (Dufour et al. 1999; Katzenberg and Weber 1999). Recent research has shown, however, that isotopic compositions in freshwater environments can be extremely variable (up to 30 ‰, Guiry

2019), and in support of this, much higher values have been reported from freshwater fish in Finland (Etu-Sihvola et al. 2022), Lithuania (Simčenka et al. 2022), and Latvia (Gunnarsone et al. 2020). Accordingly, if the diet of a population included a variety of terrestrial and freshwater resources, an overlap is expected (Webb et al. 2015).

Stable nitrogen isotope analysis reflects dietary protein. Protein can be obtained from plants, animals, and secondary animal products such as milk (Chisholm et al. 1982; Hedges et al. 2004). $\delta^{15}N$ values of different organisms generally reflect their trophic level, from primary producers (plants) to apex predators; in human archaeological remains, stable nitrogen analysis is used to gain information about the consumption of ^{15}N-enriched or depleted food sources (Hedges and Reynard 2007). The offset between the source and the consumer (for example, fauna-human) has been calculated to be between 2–6 ‰, based on previous studies (Hedges and Reynard 2007, Fernandes 2016). The presence of marine and freshwater resources in a diet will be expressed in higher $\delta^{15}N$ values in human bone collagen samples, as fish can have substantially higher $\delta^{15}N$ values compared to terrestrial resources (Katzenberg 1989; 2008, 426).

Apart from diet, a significant rise in $\delta^{15}N$ values can also be caused by physiological factors such as breastfeeding, whereby the child's $\delta^{15}N$ values rise one trophic level above the person breastfeeding them (Fogel et al. 1989); nutritional stress (Steele and Daniel 1978, Fuller et al. 2005, Beaumont and Montgomery 2016), and possible physiological stress *in utero* (Beaumont et al. 2015).

1.2 Subsistence strategies at Čunkāni-Dreņģeri, based on archaeological evidence, and previously obtained isotope data from contemporary faunal remains

The main mode of subsistence of the Iron Age Semigallians, as well as other cultures in the region, was farming, as suggested by the fact that 80 - 90% of all faunal remains found in the known settlement sites, mainly hillforts, are from domestic livestock (Apals and Mugurēvičš 2001; Atgāzis 2001). Regional differences in farming strategies were expressed in the preferred domestic livestock species. For example, archaeological data from the hillforts of Tērvete and Mežotne suggest that during the 9th – 12th centuries CE cattle was the dominant species in these Semigallian settlements. From smaller animals, pigs were preferred to sheep and goats (Atgāzis 2001). This is in contrast to Latgallian hillforts near Daugava, where pigs were the dominant species, followed by sheep and goats, and to a lesser extent, cattle (Mugurēvičs 1977, 89 – 90).

With regard to the crops grown in the fields, archaeological evidence has been found for barley (*Hordeum vulgare*), wheat (*Triticum sp*.), oats *(Avena sativa),* rye *(Secale cereale)*, broad beans (*Faba bona*), peas (*Pisum savitum*), flax (*Linium usitatissimum*), millet (*Panicum millacuem*), and turnips (*Brassica campestris*) (Rasiņš and Tauriņa 1983).

The location of the cemetery close to the river Mēmele suggests that the people from the Čunkāni – Dreņģeri population also had access to freshwater resources. Fish bones have been analysed from the Semigallian hillfort of Tērvete, obtained during archaeological excavations in 1954-55. These relate to the late Iron Age, which is slightly more recent than the Čunkāni-Dreņģeri cemetery and include 17 species in total. Most fish are believed to have been caught in the nearby Tērvete river, such as bream *(Abramis brama)* and pike (*Esox lucius*), but there was also evidence for migratory fish such as salmon (*Salmo salar*) and common whitefish (*Coregonus lavaretus*), which mainly live in the sea, but migrate into the rivers to spawn in the autumn. Two species of marine fish were also found, Atlantic herring (*Clupea harengus*), and Atlantic cod (*Gadus morhua*). These fish were most likely caught in the North Sea and preserved in salt or dried, which allowed their transportation to inland locations via trade routes (Sloka 1986, 131 – 134). These two species of marine fish have also been found in settlements and hillforts in the lower reaches of River Daugava (Sloka 1979). It is worth mentioning that the date of these fish in Tērvete coincides with the so-called "fish event horizon" in Europe in the 11th – 12th centuries CE, whereby cured Atlantic cod and herring rapidly began to dominate the growing long-distance fish trade (Barrett et al. 2004).

Based on archaeological evidence, it is likely that diet in the Čunkāni-Dreņģeri population will include terrestrial resources comprising both, C_3 and C_4 plants, domestic livestock, and probably also freshwater and marine resources, although the proportions of these food sources are currently unclear.

There is no comparative archaeological faunal carbon and nitrogen isotope data from the Čunkāni-Dreņģeri cemetery, or indeed from the Semigallian cultural area, which partly extended into the present-day territory of Lithuania (Fig. 1), and it is therefore difficult to establish an isotopic baseline in the human population. This lack of samples has two main reasons, poor preservation, and the practice of discarding all faunal remains obtained during past excavations after the identification of species. Instead, previously acquired mean faunal isotope values from two contemporary hillforts in other regions, Daugmale, and Aizkraukle (Gunnarsone et al. 2020, Fig. 1), and the

Latgallian Lejasbitēni human population (Pētersone-Gordina et al. 2022, Fig. 1), will be used for comparison.

As a part of this study, previously published comparative isotope data were also gathered from most other cemetery populations of Latvia which have been subject to dietary isotope analysis from various periods, from Stone Age to post-medieval period. This was done to investigate if and how diet in Iron Age populations was different than in other prehistoric and historical populations.

2. MATERIAL

The Čunkāni-Dreņģeri Iron Age cemetery was located on the right bank of River Mēmele, approximately 2 km from the merging of Mēmele and Mūsa, which at that point form one of the biggest rivers in Latvia, River Lielupe (Fig. 1). The burials were located in fluvial Terraces II and III of the river and cover approximately 9 ha in total. Since 1924, 743 burials have been uncovered during archaeological excavations (Atgāzis 1994a; Lūsēns 2012) and these date from the Iron Age of the Semigallian culture (7^{th} – 11^{th} centuries CE) according to grave goods and radiocarbon dates (Table 1S, Supplementary Information A). The cemetery has not been fully excavated, and its area has been considerably disturbed by modern agricultural activity. Likewise, many burials were looted in antiquity.

The burials were in dense rows, which was common in Semigallian cemeteries from the same period. Burial depth was between 30 and 90 cm, and the distance between burials in the same row was from 10 to 15 cm. The rows were gradually filled with burials from the central part of the cemetery towards the outside edges. There were 18 rows of burials in Terrace II (Fig. 2), which were organised parallel to each other in an elliptical form, but in Terrace III there were 11 rows organised in a half circle (Atgāzis 1994a, 29). This suggests that there was no particular orientation of the burials either in general, or between male and female individuals, in contrast to Latgallian cemeteries dating from the 8^{th} – 9^{th} centuries CE, where opposite burial orientation was observed for male and female gender individuals (Atgāzis 1994a, 30). Archaeologists have suggested that each row may have contained members of the same family (Atgāzis 2001, 281), but this possibility has not yet been explored by scientific analysis such as aDNA.

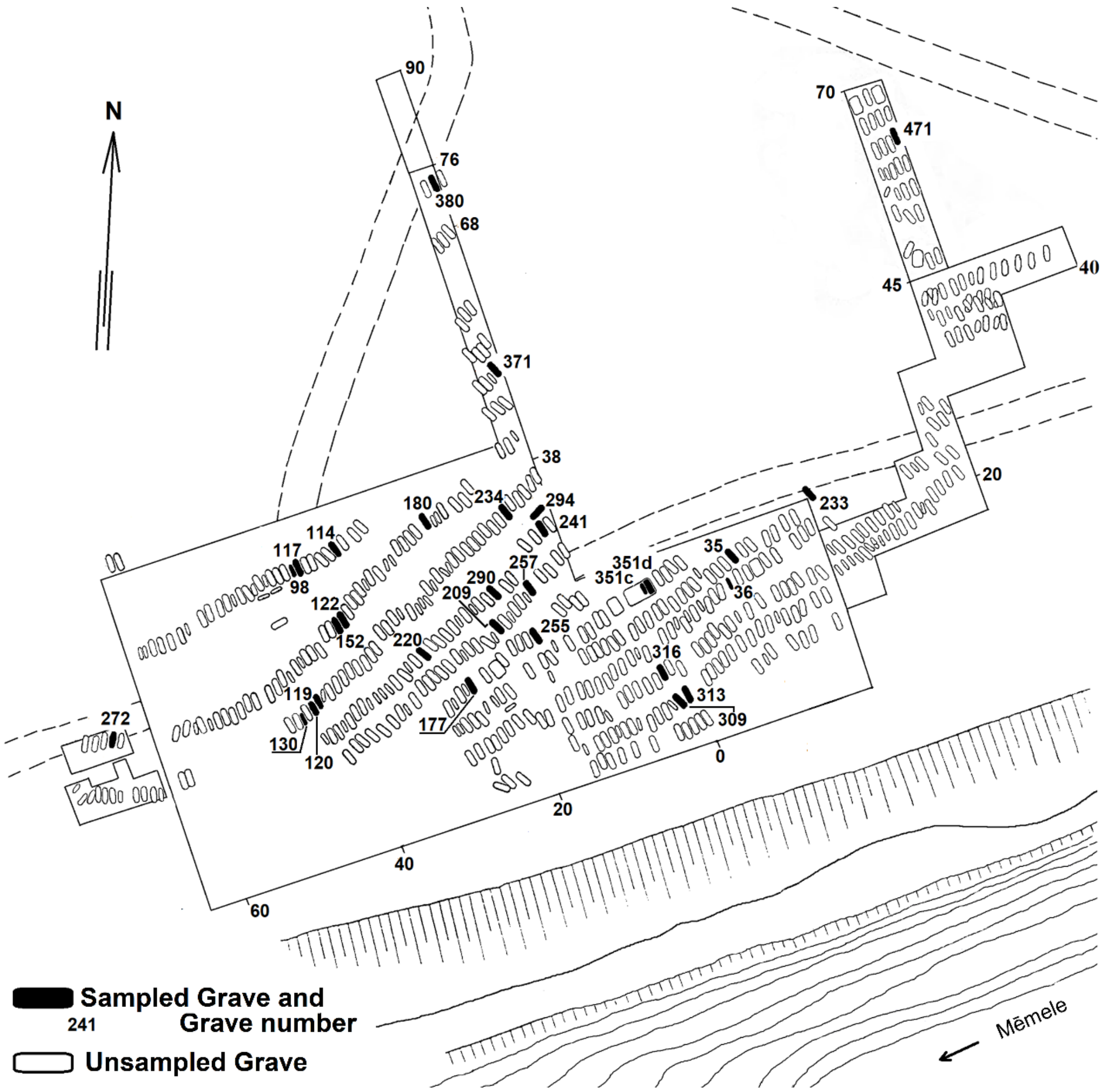

Fig. 2 Plan of Terrace II burials at the Čunkāni-Dreņģeri cemetery, showing burials sampled for isotope analysis (filled in black), redrawn and supplemented by A. Vilcāne from Atgāzis (2001, 273; Figure 194)

The skeletal remains from burials located in the fluvial Terrace III of Mēmele had been practically completely eroded by the clay soil. Human bone had survived well in Terrace II burials thanks to gravel and dolomite which dominate the soil there. In total, 533 burials were recovered from Terrace II, and the preservation of bones allowed for bioarchaeological and biochemical (stable isotope analysis and radiocarbon dating) analyses. Of these, 35 burials could not be assigned an age (adult or non-adult) or gender, therefore these were not included in the current research.

Regardless of the considerable damage to the cemetery a wide range of grave goods have been obtained, providing a valuable tool for studying the Semigallian culture. This material has not yet been studied in detail and published, but it is curated at the National History Museum of Latvia. The documentation and the skeletal material from the excavations is stored at the Repository of Archaeological Material, and the Repository of Bioarchaeological Material, Institute of Latvian History, University of Latvia, respectively.

The number of burials selected for dietary analysis (N=29) was dependent on the allocated funding within this project, therefore the sampling strategy targeted burials representing different age (adult and non-adult) and gender groups from various areas of the cemetery, giving preference to those with good bone preservation and with no, or minimal, evidence for disturbance. Although rib was the preferred sample type (N=18), it was not possible for all burials due to differential preservation, and other bones had to be selected, including skull (N=6), scapula (N=2), and one each a maxilla, a hand phalanx, and a clavicle. Mixing of samples might skew individual isotope values due to differential rates of bone remodelling, especially between the skull and other bones of the skeleton, but it is unlikely to be significant on a population level (Fahy et al. 2017). All sampled burials are shown in Fig. 2.

To study if social status was related to diet, samples were also taken from burials of differential social status, as expressed by grave goods. As discussed above, for male gender burials, higher status might have been expressed by more spearheads in the grave. For this reason, four male individuals with three and more spearheads were selected for dietary isotope analysis (Burials 117 and 220 with three spearheads and burials 209 and 241 with five spearheads). With regard to female individuals, the selection of burials with potentially higher social status was difficult because many had been disturbed by grave robbers, who likely had removed any artefacts regarded as valuable. Despite these limitations, female gender Burial 316 was one of the most richly decorated in the Čunkāni-Dreņģeri cemetery and was selected as potentially representative of high social status.

Three archaeological outliers were also selected to see if the differences in terms of burial ritual, and/or the grave goods given, were expressed in differential diets during lifetime. Female gender Burial 294 (aged 30-35 years) contained few artefacts and was buried perpendicularly to the richly decorated Burial 241 of a male gender individual with five spearheads, mentioned above (aged over 40 years, Fig. 3). Burial 471, a non-adult individual was regarded as an archaeological outlier because their grave inventory contained a heavy narrow-bladed axe, which is a rare item among Semigallian non-adult burials dating from the 7th – 9th centuries CE, but more common in contemporary Latgallian burials, including in the Lejasbitēni cemetery (Atgāzis 2019, 133).

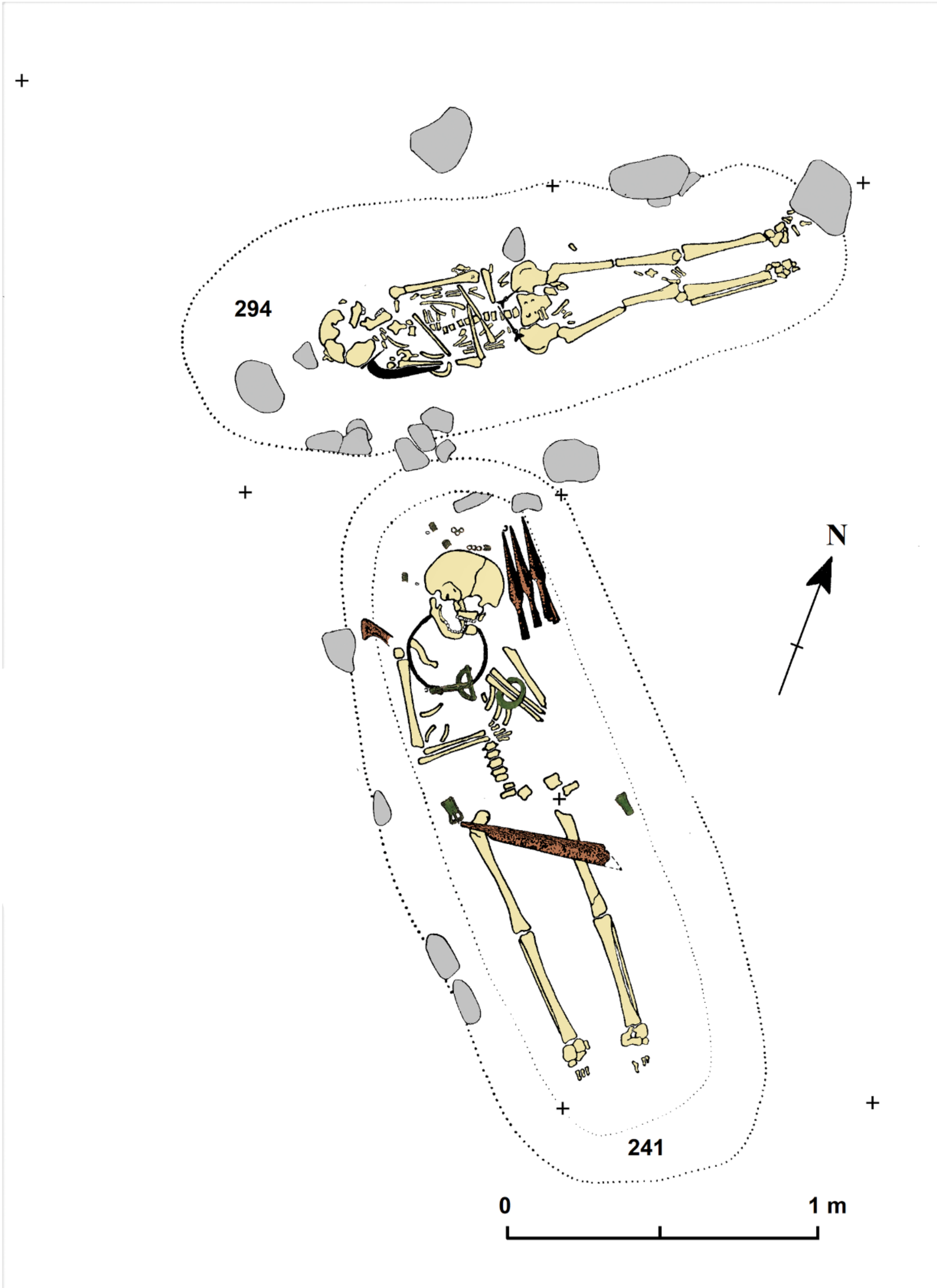

Fig. 3 The plan of Burials 241 and 294 from the Čunkāni-Dreņģeri cemetery, redrawn by A. Vilcāne from Atgāzis (1994b, 31; Figure 2)

3. METHODS

3.1 Estimation of sex, gender, and age

Gender was estimated in adult and non-adult individuals based on grave inventory (weapons, tools, jewellery, etc.). Despite the large number of disturbed burials, most adult individuals could also have their biological sex estimated based on the morphology of the pelvis and skull, and their skeletal age estimated based on age-related changes in the pelvis and other skeletal elements (Buikstra and Ubelaker 1994, 16-26). Age in non-adult individuals was based on tooth development stages (AlQahtani et al. 2010), or long bone length, where dentition was not observable (Fazekas and Kósa 1978; Maresh 1970).

The chronology of the burials was determined based on grave goods, as well as radiocarbon dating (^{14}C), carried out at the Poznan Radiocarbon Laboratory (Supplementary Information A). Most burials which had been selected for isotope analysis had been archaeologically dated to the 7th – 9th centuries CE (N=21), five dated from the 9th – 10th centuries CE, and just three were from the 10th – 11th centuries CE (Table 4). Sample selection for radiocarbon dating was carried out simultaneously with sample selection for isotope analysis (see below), and was based on the allocated budget, the location of burials, and archaeological information, so as to obtain a wide range of dates.

3.2 Assessment of social status

Identifying social status in life through grave goods in the Čunkāni-Dreņģeri cemetery was difficult because of the high number of disturbed and robbed burials, and therefore studying any differences between people of varying social status was only possible on an individual level. To achieve this, grave goods were used as an indicator of social status, with an understanding that these items might not have necessarily belonged to the deceased during their lifetime but were instead given to them as a part of the burial ritual. Moreover, it is possible that only particular types of grave goods can be regarded as representative of an individual's social status (Carr 1995), and this might have been true for the number of spearheads in Semigallian male burials, as mentioned in Section 1.

3.3 Carbon and nitrogen stable isotope analysis

Details of sample preparation and analysis are provided in Supplementary Information B. Calibration using internal reference samples (e.g., Glutamic Acid, Glycine, SPAR and Urea) and international reference standards (e.g., USGS 24, USGS 40, IAEA 600, IAEA N1, IAEA N2) determined a standard deviation of ±0.1‰ (1σ) for collagen carbon and nitrogen isotopes.

4. RESULTS

4.1 Results of osteological and archaeological analysis

Out of 533 burials, 498 could be used for osteological and archaeological analysis. There were 355 adults (71.29%) and 143 non-adults (28.71%), but no children aged younger than 1.5 – 2 years. The lack of very young children in this cemetery is likely to be the result of burial traditions in Iron Age cemeteries, whereby not all individuals were buried in cemeteries (Gerhards 2002), rather than mortality patterns in this age group (osteological paradox, DeWitte and Stojanowski 2015). Biological sex could be estimated in about 70% of adult individuals. The results for gender and age estimation are summarised in Table 1. Non-adult age groups are summarised in Table 2. For a number of adult and non-adult burials, gender could not be determined due to a lack of grave goods, either because of grave robbing, or simply because few grave goods were given at burial. This was particularly the case for non-adults, who, unlike adults, were less frequently buried with tools (for female gender burials), and were very rarely given weapons, or their miniature forms (for male gender burials). For this reason, the real differences in the proportion of male and female gender non-adult burials might not have been as considerable as shown in Table 1.

Table 1 Distribution of male and female gender groups by age (adult and non-adult), in the Čunkāni-Dreņģeri cemetery

Adults	**N**	**%**
Male gender	155	31.12
Female gender	138	27.71
Unknown gender	62	12.45
Non-adults	**N**	**%**
Male gender	37	7.43
Female gender	62	12.45
Unknown	44	8.84
Total	**533**	**100**

Table 2 Non-adult age groups in the Čunkāni-Dreņģeri cemetery

Age group (years)	**Male gender**	**Female gender**	**Unknown gender**	**Total**
0 - 1	0	0	0	0
1 - 4	11	14	15	40
5 - 9	10	17	11	38
10 - 14	9	10	8	27

15 - 19	6	11	6	23
Unknown age	1	10	4	15
Total	37	62	44	137

Radiocarbon dates of the Čunkāni-Dreņģeri cemetery are in agreement with the typology of artefacts and generally support the chronology of the site, suggesting that the cemetery was used from the middle of the 7th century until the middle of the 11th century cal. CE (Table S1, Supplementary Information A).

4.2 Dietary isotope results

Quality control parameters for the collagen analysed were all good, with %C, %N and C:N ratio all falling within the ranges suggested by van Klinken (1999) and Guiry and Szpak (2021).

In this population, the range of δ^{15}N values within two standard deviations of the mean was between 7.4 ‰ and 10.1 ‰, and δ^{13}C values between -21.4 ‰ and -20.4 ‰ (Table 3, Fig. 4). Four outliers were determined, based on their δ^{13}C or δ^{15}N values exceeding two standard deviations of the mean, and these were Burials 98 (δ^{13}C value -19.96), and 177, 233, and 471 (δ^{15}N values 10.87, 11.20, and 12.15, respectively, Fig. 4 and Supplementary Fig. 1S). All isotopic outliers were of male gender. The minimum, maximum, and mean values are summarised in Table 4, and the distribution is shown in Fig. 1S.

Table 3 Sampled individuals from the Čunkāni-Dreņģeri cemetery (N=29), sample types, and results of carbon and nitrogen stable isotope analysis

Burial #	**Gender**	**Sex**	**Age**	**Sample type**	**%N**	**δ^{15}N**	**%C**	**δ^{13}C**	**C:N atomic**	**Chronology centuries CE**

180	F	?	>20	Rib	16.08	**7.43**	43.84	**-21.00**	3.2	8th
234	F	F	20-25	Rib	16.32	**8.40**	45.20	**-20.92**	3.2	7th – 8th
255	F	F	>30	Rib	16.94	**8.82**	46.87	**-20.68**	3.2	9th
272	F	?	>30	Scapula	16.34	**8.85**	45.31	**-21.28**	3.2	8th – 9th
290	F	F	20-25	Rib	16.80	**8.64**	45.84	**-20.54**	3.2	8th
294	F	F	30-35	Rib	15.76	**8.30**	43.77	**-20.69**	3.2	7th – 8th*
316	F	F	40-50	Rib	16.27	**9.70**	45.42	**-20.99**	3.3	9th – 10th*
371	F	F	25-30	Rib	16.21	**7.95**	45.93	**-21.04**	3.3	7th – 8th
36	F	?	10-12	Rib	16.42	**8.68**	45.23	**-20.99**	3.2	10th – 11th
114	F?	?	12-13	Rib	16.44	**8.35**	44.68	**-20.59**	3.2	7th – 8th
120	F	?	6-7	Maxilla	16.31	**7.94**	44.56	**-20.81**	3.2	8th – 9th
152	F	?	12-15	Rib	16.38	**8.48**	45.12	**-21.27**	3.2	8th
117	M	M	40-50	Skull	14.37	**7.68**	39.70	**-20.84**	3.2	8th
122	M	M	45-55	Rib	16.46	**8.50**	45.39	**-21.21**	3.2	8th
177	M	M	50-60	Skull	16.51	**10.87**	45.54	**-21.26**	3.2	8th – 9th
209	M	M	35-40	Rib	16.75	**8.27**	44.77	**-20.82**	3.1	8th – 9th
220	M	M	>30	Hand phalanx	16.34	**9.12**	44.76	**-20.79**	3.2	8th – 9th
233	M	M	45-50	Rib	16.47	**11.20**	43.76	**-20.63**	3.1	9th – 10th
241	M	M	>40	Rib	16.14	**8.37**	45.52	**-20.94**	3.3	7th – 8th*
309	M	M	35-45	Scapula	16.92	**9.13**	46.51	**-20.91**	3.2	10th – 11th
313	M	M	>30	Clavicle	17.02	**8.78**	47.08	**-21.37**	3.2	10th – 11th
351c	M	M	45-55	Rib	16.27	**9.06**	44.96	**-20.88**	3.2	9th – 10th
380	M	M	>30	Skull	16.83	**8.93**	46.44	**-20.70**	3.2	7th*
35	M	?	13-14	Rib	15.58	**7.62**	42.49	**-21.13**	3.2	9th – 10th
98	M	?	5-6	Skull	16.17	**10.14**	44.23	**-19.96**	3.2	8th
119	M	?	7-8	Rib	16.66	**8.21**	45.92	**-20.56**	3.2	8th – 9th
130	M	?	5-6	Rib	16.54	**9.46**	45.12	**-20.43**	3.2	8th – 9th
351d	M	?	13-14	Skull	15.88	**8.80**	43.68	**-21.09**	3.2	9th – 10th*
471	M	?	7-9	Skull	16.49	**12.15**	45.65	**-20.63**	3.2	8th – 9th

M-male, F-female; *dated by ^{14}C

Table 4 Summary of minimum and maximum δ^{15}N and δ^{13}C values in males and females from the Čunkāni-Dreņģeri cemetery, by gender

Gender	**δ^{15}N values ‰**				**δ^{13}C values ‰**			
	Min (burial)	Max (burial)	Mean	SD	Min (burial)	Max (burial)	Mean	SD
F	7.43 (180)	9.70 (316)	8.46	0.57	-21.28 (272)	-20.54 (290)	-20.90	0.24
M	7.62 (35)	12.15 (471)	9.19	1.24	-21.37 (313)	-19.96 (98)	-20.83	0.34
Overall	7.43 (180)	12.15 (471)	8.89	1.07	-21.37 (313)	-19.96 (98)	-20.86	0.30

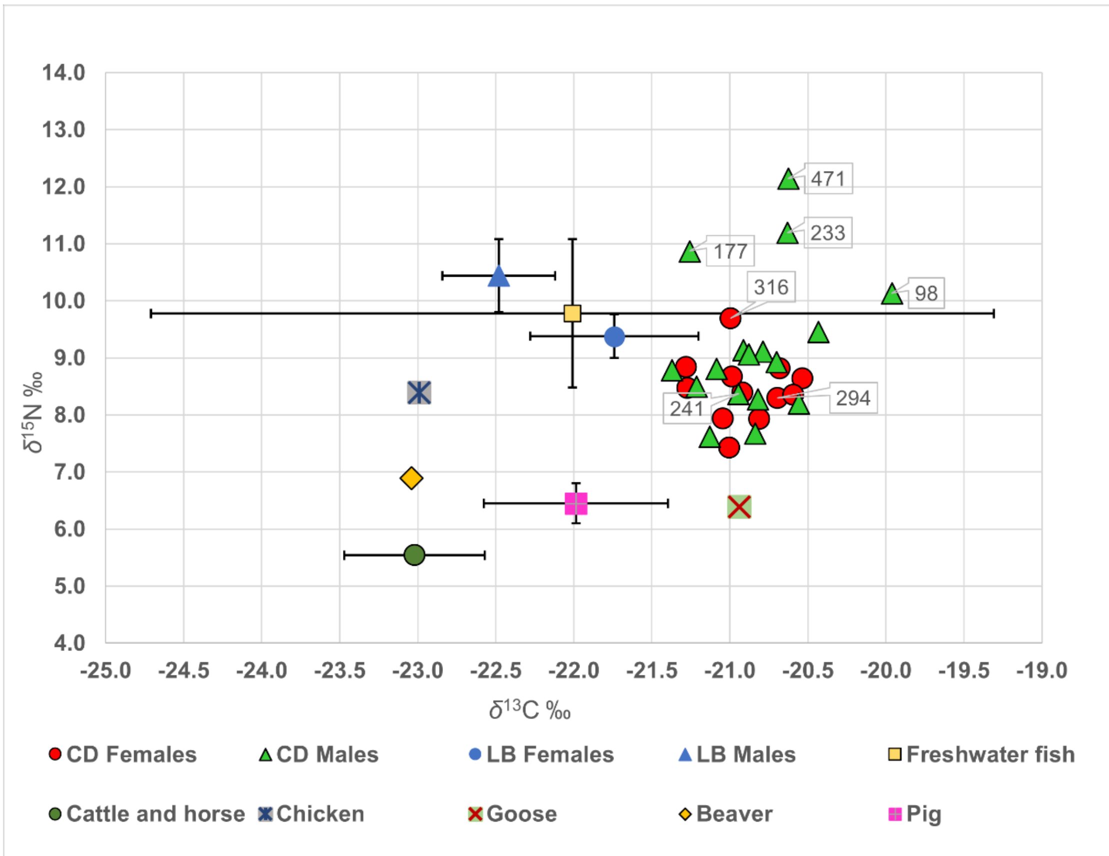

Fig. 4 δ^{15}N and δ^{13}C values in the Čunkāni-Dreņģeri male (N=17) and female (N=12) gender individuals, showing the four male gender outliers with their burial numbers, the richly decorated female burial 316, as well as the perpendicular male and female burials discussed above (241 and 294), against mean Lejasbitēni human values (LB males, N=14, LB females, N=15, from Pētersone-Gordina et al. 2022), and faunal values, showing 1SD of the mean for human values, and faunal values with more than one sample (cattle and horse, N=2, respectively; domestic pig, N=2; freshwater fish, N=13, from Gunnarsone et al. 2020)

Due to the small sample sizes, statistical analysis of the isotope results was performed with the non-parametric Mann-Whitney test, using Vassar stats Website for Statistical

Computation (Lowry 1998-2023). This tests a null hypothesis of no difference in median values between two samples.

δ^{15}N values were not significantly different between male (N=17) and female (N=12) gender individuals (U=63, z=1.7, p=0.0891, difference in medians 0.5 ‰, Fig. 4). There were also no significant differences in δ^{15}N values between adults (N=11) and non-adults (N=6) of male gender (U=35, z=-0.15, p=0.8808, difference in medians 0.2 ‰) or female gender (N=8 and N=4, respectively; U=13, lower limit 4, upper limit 26, difference in medians 0.1 ‰). When analysed by age group, the higher δ^{15}N values in male gender children (N=6) were not significant compared to those in female gender (N=4) children (U=7, lower limit 2, upper limit 22, difference in medians 0.7 ‰). Likewise, there were no significant differences in δ^{13}C values between the male and female gender groups (U=91, z=0.46, p=0.6455, difference in medians 0.1 ‰), as well as between female (U=16.5, lower limit 4, upper limit 28, difference in medians 0.1 ‰) and male gender adults and children (U=49.5, z=-1.61, p=0.1074, difference in medians 0.2 ‰).

When compared to the Lejasbitēni Iron Age population (N=29, male gender N=14, female gender N=15), it emerged that the population of Čunkāni-Dreņģeri was isotopically significantly different by both, δ^{15}N and δ^{13}C values (Fig. 4, overall δ^{15}N values U=145, z=4.28, p=<.0001, difference in medians 1.0 ‰; overall δ^{13}C values U=841, z=-6.53, p=<.0001, difference in medians 1.8 ‰). The differences in gender groups between both populations were also statistically significant (female δ^{15}N values U=18, z=3.37, p=0.0004, difference in medians 0.9 ‰; δ^{13}C values U=168, z=-4.29, p=<.0001, difference in medians 0.9 ‰; male δ^{15}N values U=196, z=-3.04, p=0.0012, difference in medians 1.2 ‰, δ^{13}C values U=0, z=4.7, p=<.0001, difference in medians 1.6 ‰), indicative of overall higher δ^{13}C and lower δ^{15}N values at Čunkāni-Dreņģeri.

5. DISCUSSION

5.1 Subsistence strategies at Čunkāni-Dreņģeri

On a population level, subsistence strategies as expressed in dietary isotope values point to a mainly terrestrial C_3 food-chain diet in this population, while the presence of freshwater resources is currently unclear. The mean δ^{13}C value at Čunkāni-Dreņģeri (-20.86 ‰) was comparable to other regional archaeological sites with mainly C_3 food-chain diets, including Alytus in Lithuania (N=73, 14th – 18th centuries CE, -20.08 ‰ ±0.26, Whitmore et al. 2019) and western Lithuania (N=3, 3rd – 5th centuries CE, -20.6 ‰ ±0.4, Bliujienė et al. 2020). The mean δ^{15}N values for these sites were higher than at Čunkāni-Dreņģeri (8.89 ‰), indicating a more ^{15}N-rich animal protein source (10.29 ‰ and 11.0 ‰, respectively).

In archaeological sites from the wider region where either freshwater or marine, or both sources were included in the diet, mean δ^{13}C values were still indicative of mainly terrestrial C_3 foodchain diets, and thus broadly comparable to Čunkāni-Dreņģeri, but the mean δ^{15}N values were all considerably higher, again indicating more ^{15}N-rich animal protein sources. These sites included Estonian Kaberla (N=29, 12th – 16th centuries CE, -19.8 ‰ ±0.3; 10.4 ‰ ±0.8), St Barbara (N=30, 12th – 16th centuries CE, -20.0 ‰ ±0.6; 11.2 ‰ ±1.0, both sites Aguraiuja-Lätti and Lõugas 2019), and Kukruse (N=30, 12th -13th centuries CE, -20.83 ‰ ±0.3; 10.45 ‰ ±1.0, Oras et al. 2018).

Although slightly further geographically, the same was true for the Finnish site of Luistari (N=54, 7th – 11th centuries CE, -20.1 ‰ ±0.5; 13.2 ‰ ±0.9, Etu-Sihvola et al. 2022), and the Swedish Viking Age and medieval sites of Birka (N=19, 8th – 9th centuries CE, -20.0 ‰ ±0.6; 13.6 ‰ ±1.1, Linderholm et al. 2008) and Sigtuna (N=76, 12th – 14th centuries CE, -21.06 ‰ ±0.4; 12.33 ‰ ±1.0, Kjellström et al. 2009).

On an individual level, diet at Čunkāni-Dreņģeri might have been different for the four male gender isotopic outliers who had higher δ^{15}N and/or δ^{13}C values (Fig. 4). The differences might have included a different source of animal protein, aquatic resources (including marine), and possibly, millet for Burial 98. A non-local origin for these individuals is also possible. On the other hand, it has to be taken into account that the statistical method used to identify isotopic outliers in this research (±2SD) can result in a higher proportion of outliers because of the small sample size (Lightfoot et al. 2016, Seo 2006).

5.2 Access to resources between individuals of higher and lower social status, as expressed by grave goods

Although the sample size was small, dietary isotope analysis shows that there were no significant differences between gender groups, age groups, or individuals with differential social status, rejecting the hypotheses of this study. This was especially true when comparing the male gender burials with differences in the number of spearheads given as grave goods. Indeed, individuals from Burials 209 and 241 (Fig. 5) with five spearheads were within the range of both δ^{15}N and δ^{13}C values (8.27 ‰ and -20.82 ‰, and 8.37 ‰ and -20.82 ‰, respectively). The same was true for the two burials with three spearheads, although they did show comparatively higher $\delta^{15}N$ values (Burial 220, 9.12 ‰ and -20.79 ‰, and Burial 117, 7.68 ‰ and -20.84 ‰). The lack of significant differences between these burial types is interpreted as a lack of social differentiation in diet, based on the currently available evidence. This suggests that while the number of spearheads in burials might have expressed differential social status in life, this difference had no effect on diet in the tested individuals. Likewise, the $\delta^{15}N$ value of the female individual from the richly furnished Burial 316 (an old middle adult, 9.70 ‰ and -20.99 ‰) was 0.77 ‰ higher than the second highest female value, 8.93 ‰, but the difference was not big enough to make this burial an isotopic outlier.

Fig. 5 Grave inventory of male gender Burial 241 from the Čunkāni-Dreņģeri cemetery. Numbers 1, 6 – clothing decorations; 2-4 jewellery (bronze neck ring, cross-bow brooch, arm band); 5,7- bronze belt buckle and fitting; 8-14 weapons (iron battle knife, spearheads, narrow bladed axe). The artefacts are stored in the National History Museum of Latvia (LNVM LVI 250: 67—80). Photograph by A. Vilcāne

Although this individual might have had access to a different animal protein source compared to other females, the link between her diet and higher social status as expressed in grave goods remains unclear, especially because Burial 316 is one of only five from a slightly later period (10th century CE) than most other burials selected for isotope analysis (Table 4). The higher $\delta^{15}N$ value in this individual might also have occurred due to reasons other than diet, for example, physiological stress.

Due to the small number of burials which could be classed as high or low social status based on grave goods, no statistical analysis was possible. Archaeological evidence from the local region suggests that burials dating from the 8th and 9th centuries CE in the Čunkāni-Dreņģeri cemetery can be regarded as characteristic for the time, pointing to a high degree of homogeneity in the Semigallian society during this period (Tautavičius 1996; Ligi 1995), which was also expressed in equal access to animal protein, according to the currently available isotope data.

In terms of dietary differences for two of the archaeological outliers, the $\delta^{15}N$ value of the richly furnished male gender Burial 241 (8.27 ‰ and -20.82 ‰, Figs. 3, 4 and 5) was very similar to that of the perpendicular female gender Burial 294 (8.30 ‰ and -20.69 ‰, Figs. 3, 4 and 6), thus pointing to no dietary differences between these individuals.

Fig. 6 Grave inventory of female gender Burial 294 from the Čunkāni-Dreņģeri cemetery. Number 1- iron sickle; 2,3- bronze decorative pins. The artefacts are stored in the National History Museum of Latvia (LNVM LVI 250: 296-298). Photograph by A. Vilcāne

The only archaeological outlier who also turned out to be different isotopically was Burial 471 (a male gender child with a rare item for a non-adult in grave inventory, 12.15 ‰ and -20.63 ‰). As mentioned above, it is possible that this individual, and the other three male gender isotopic outliers (Burials 177, 10.87 ‰ and -21.26; 233, 11.20 ‰ and -20.63; and 98, 10.14 ‰ and -19.96 ‰) were not local to the Čunkāni-Dreņģeri population. The local or non-local origin of all these individuals will be explored in the future with strontium and oxygen isotope analysis.

With regard to the hypothesis that the two Latvian Iron Age populations would be isotopically similar, especially in terms of differential diet for gender groups, it was rejected. There were no statistically significant differences between males and females at Čunkāni-Dreņģeri. There is evidence, however, for external cultural influence in both populations, with the changes at Lejasbitēni taking place from the 9th century CE, and at Čunkāni-Dreņģeri from the 10th century CE, which coincides with the Viking Age. During the late Iron Age (10th – 12th centuries CE) in the Semigallian cultural area, the scale of grain production allowed for accumulation of large amount of grain. For example, a grain store with capacity of at least 18 tonnes, was uncovered at Tērvete hillfort (Fig. 1) with evidence for storage of barley, wheat, rye, and peas (Banyté-Rowell et al. 2003, 74). It is possible that during this period the Semigallian people traded the surplus grain with Scandinavia (Atgāzis 2001, 266). At Čunkāni-Dreņģeri, this possibility is supported by the change from uniformity in grave goods in burials from the 7th – 9th centuries CE, to inclusion of more elaborate items from the 10th century CE onwards. These included elaborate jewellery items (e.g., Burials 316 and 309), and weapons and accessories such as silver-encrusted sockets of spearheads (Burials 396 and 412) and ornamented battle knife sheaths (Burial 320), all probably imported from Viking Age Scandinavia (Atgāzis 1992, 1994a).

Around this time, inverted burial orientation for male and female gender individuals also occur at Čunkāni-Dreņģeri. It is therefore possible that social stratification in this population increased in the 10^{th} – 11^{th} centuries CE in response to changes in trade, but this could only be traced through individual burials, rather than on a population level, due to the disturbance of many graves from this period. The Viking Age is known to have brought social stratification to other remote, previously homogenous populations, for example, the Orkneys (Barrett and Richards 2004; Richards et al. 2006), and this might have also been true for the Iron Age populations in Latvia. The differences in the timing of changes in burial traditions between Lejasbitēni and Čunkāni-Dreņģeri suggest that the advance of the Viking Age differed within this relatively small geographical area, probably due to the distance of the sites from major international trade routes used at the time, and inter-cultural relations. To explore the advance of the Viking Age in Latgallian and Semigallian populations further, similar data from other contemporary cemeteries are necessary.

Significantly different δ^{13}C and δ^{15}N values between the two Iron Age populations suggest that although both lived in the same time period, and close to rivers, their subsistence strategies were different, perhaps particularly with regard to the consumption of freshwater resources, according to the currently available data. It is possible that arable and livestock farming provided the Čunkāni-Dreņģeri population with sufficient food supplies throughout the year, while the practice of using resources from the river remained important in the Lejasbitēni population. The differences might have been partly caused by differential soil fertility in both sites. For example, the Zemgale plateau, in which the Čunkāni-Dreņģeri cemetery is located, is dominated by a web of rivers, and covered by carbon rich clay soils, which are among the most fertile in the Eastern Baltic region and therefore particularly suitable for growing grains. In contrast, the soils in the region where the Lejasbitēni cemetery is located are among the poorest in Latvia (Eglīte 2016).

5.4 Multiperiod comparison of dietary isotope data

In order to see how dietary practices changed through time in Latvia, and how Iron Age populations compare to other periods, previously published data from all archaeological populations in Latvia which have been subject to dietary isotope analysis to date, were gathered (Figs. 7 and 8). Data from the Stone Age hunter-gatherer populations were available from the Zvejnieki population (7000 - 3200 cal BCE, N=37, Eriksson et al. 2003; Eriksson 2006; Meadows et al. 2018; Zagorska 2006), and the Riņņukalns population (3960 - 3650 cal BCE, N=3, Lübke et al. 2016; Bērziņš et al. 2014), data from the Bronze Age were available from the agricultural Ķivutkalns (800 - 342 cal. BCE, N=8 for δ^{15}N values, N=13 for δ^{13}C values, Vasks and Zariņa 2014; Legzdiņa et al. 2020) and Reznes populations (1226 - 545 cal. BCE, N=6, Legzdiņa et al. 2020), while the medieval period was represented by the rural Ikšķile population (13th - 15th centuries CE, N=7, Zariņa 2016), and the post-medieval period by the urban non-adult population of Jelgava (17th – 18th centuries CE, N=7, Petersone-Gordina et al. 2018), and suburban St Gertrude population from Riga (16th – 18th centuries CE, N=96, Petersone-Gordina et al. 2018). The mean δ^{13}C and δ^{15}N values and standard deviations are summarised in Supplementary Information C, Table 2S.

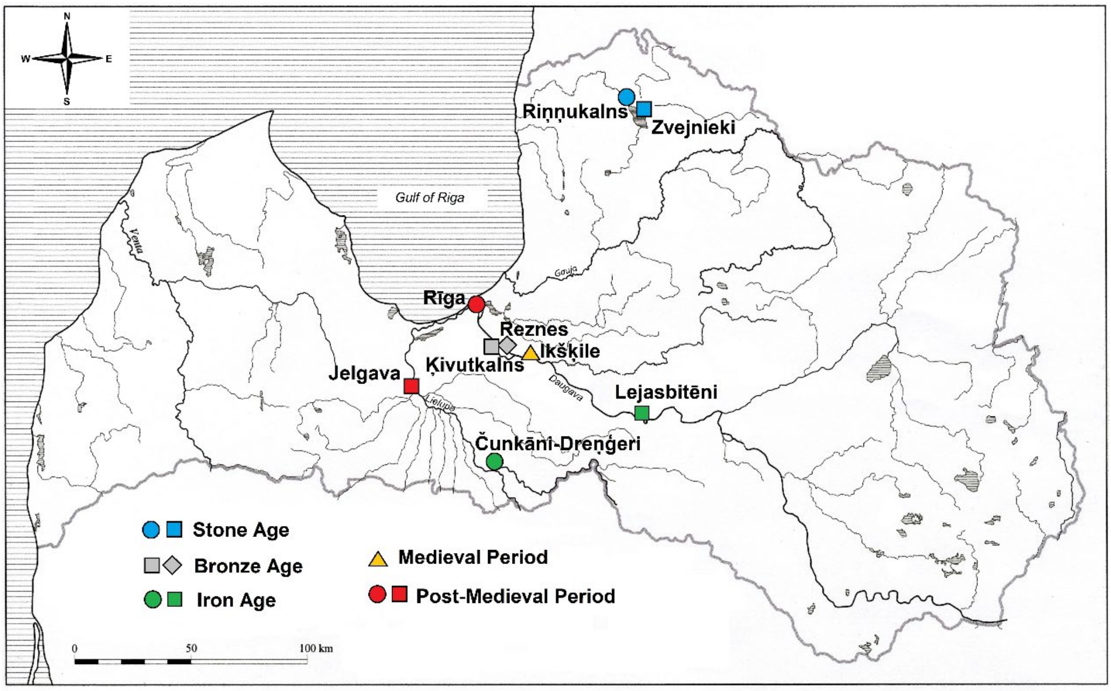

Fig. 7 Locations of the comparative Latvian archaeological sites with human isotope data

While detailed comparative analysis was beyond the scope of this study, some clear patterns emerged with regard to the dietary practices of these populations.

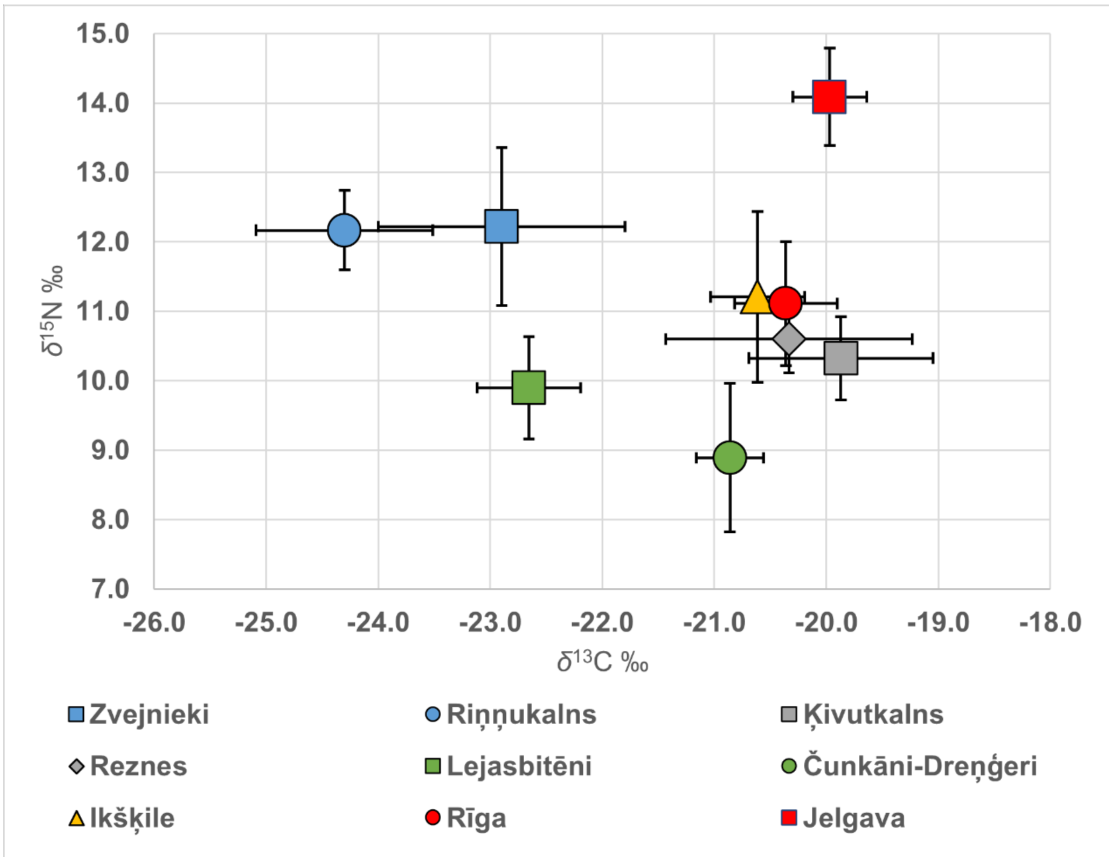

Fig. 8 Mean δ^{13}C and δ^{15}N values and standard deviations (1) of Stone Age (Zvejnieki, N=37 and Riņņukalns, N=3; Eriksson et al. 2003; Eriksson 2006; Meadows et al. 2018; Lübke et al. 2016; Bērziņš et al. 2014; Zagorska 2006), Bronze Age (Ķivutkalns, N=13; Vasks and Zariņa 2014; and Reznes, N=6; Legzdiņa et al. 2020), Iron Age (Lejasbitēni, N=29; Pētersone-Gordina et al. 2022, and Čunkāni-Dreņģeri, N=29) Medieval (Ikšķile, N=7; Zariņa 2016), and post-medieval (Jelgava, N=7; and Riga, N=96; Petersone-Gordina et al. 2018) human populations

The comparison revealed that both Iron Age populations were different from all others, but each in a different way. By δ^{13}C values, the Čunkāni-Dreņģeri population was much closer to Bronze Age, medieval, and post-medieval populations, albeit exhibiting a lower standard deviation than these populations (0.3 ‰, as shown in Table 4 and Fig. 8). Likewise, there is no evidence for either freshwater or marine resources, or millet, in the diet of most individuals analysed here. The population of Lejasbitēni, in contrast, was closer in the mean $\delta^{13}C$ value to Stone Age populations, rather than Čunkāni-Dreņģeri.

With regard to $\delta^{15}N$ values, similarities emerged between the two Iron Age populations, in that both had the lowest mean values among the populations compared in this study, with Čunkāni-Dreņģeri the lowest of all (8.9 ‰). This might point to a lower local faunal baseline than in the comparative populations, and/or reliance on ^{15}N depleted protein sources, such as grazing animals.

6. CONCLUSIONS

This study has reached its main aim to study the diet and possible social stratification in the Iron Age population of Čunkāni-Dreņģeri, generating the second dataset from an Iron Age population in Latvia, and complementing the currently scarce dietary isotope data from the Baltic region, in the process. On an individual level, any social stratification as expressed in grave goods, was not supported by dietary isotope data. No differential dietary patterns emerged between richly furnished burials, and/or male gender burials with more spearheads in their grave inventories, and the rest of the population.

One archaeological outlier had a different diet, expressed in an $\delta^{15}N$ value exceeding 2SD of the population mean (Burial 471). Apart from this individual, three other male gender isotopic outliers were also identified. The possible non-local origin of these individuals will be explored in future by strontium isotope analysis.

There was also dietary homogeneity between different gender and age groups during the 7th – 9th centuries CE, with some evidence for social stratification from the 10th century, when changes in trade reached this community. Both, archaeological and isotopic evidence pointed to reliance on protein sources with low δ^{15}N values in this population, while the use of freshwater resources currently remains unclear. Obtaining local faunal isotopic baseline is necessary for a more informed discussion about diet at Čunkāni-Dreņģeri.

The comparison of dietary data from Stone Age, Bronze Age, medieval and post-medieval populations from Latvia showed that the Iron Age populations had the lowest mean δ^{15}N values, suggesting reliance on ^{15}N depleted animal protein sources within their diets. The δ^{13}C values at Čunkāni-Dreņģeri were similar to those reported in most other Latvian archaeological populations from Bronze Age onwards. Likewise, on a larger regional scale, in terms of δ^{13}C values the Čunkāni-Dreņģeri population was comparable to early Iron Age and early medieval cemetery populations from Estonia, Lithuania, Finland, and Sweden, while the mean δ^{15}N value in this population remained the lowest so far among the comparative populations. The reasons for this difference and the consumption of freshwater resources at Čunkāni-Dreņģeri can only be investigated further after obtaining local faunal values and values for local freshwater resources, including molluscs.

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Ethics approval

Not applicable

Consent to participate

Not applicable

Consent for publication

Not applicable

Availability of data and material

All data generated during this research is presented in this paper and its Supplementary Information.

Code availability

Not applicable

Authors' contributions

E.P.G., G.G. and A.V. prepared the main manuscript text, A.V. prepared the maps and figures, J.M prepared samples for isotope analysis and provided the methods section about isotope analysis, A.M. helped to prepare sections about isotope analysis and statistical analysis. All authors reviewed the manuscript.

REFERENCES

Aguraiuja-Lätti, Ü. & Lõugas, L. 2019. Stable isotope evidence for medieval diet in urban and rural northern Estonia. *Journal of Archaeological Science: Reports,* 26, 101901.

AlQahtani, S. J., Hector, M. & Liversidge, H. 2010. Brief communication: the London atlas of human tooth development and eruption. *American Journal of Physical Anthropology,* 142**,** 481-490.

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

Antanaitis, I. & Ogrinc, N. 2000. Chemical analysis of bone: stable isotope evidence of the diet of Neolithic and Bronze Age people in Lithuania. *Istorija,* 45**,** 3-12.

Apals, J. & Mugurēvičš, Ē. 2001. Vēlais dzelzs laikmets (agrie viduslaiki) 800. -1200. g [Late Iron Age (early medieval period) CE 800-1200]. *In:* Apals, J., Atgāzis, M., Graudonis, J., Loze, I., Mugurēvičs, Ē., Vasks, A. & Zagorska, I. (eds.) *Latvijas senākā vēsture.* Riga: Latvijas vēstures institūta apgāds, pp. 232-289.

Arnold, B. 2006. Gender in mortuary ritual. *In:* Nelson, S. M. (ed.) *Reader in Gender Archaeology.* Walnut Creek: AltaMira, pp. 137-170.

Atgāzis, M. 1994a. Dreņģeru-Čunkānu kapulauks un zemgaļu senvēstures pētniecības jautājumi [Dreņģeri-Čunkāni cemetery and the history of ancient Semigallian culture]. *Zinātniskās atskaites sesijas materiāli par arheologu 1992. un 1993. gada pētījumu rezultātiem.* Riga: Zinātne, pp. 23-30.

Atgāzis, M. 1994b. Dreņģeru—Čunkānu 241. kaps un šķēpu līdzdošanas tradīcija 8.—9. gs. zemgaļu apbedījumos [Burial 241 of the Dreņģeri-Čunkāni cemetery and the Semigallian tradition of placing spearheads in burials from the 8th-9th centuries CE]. *Arheoloģija un etnogrāfija, 17. laidiens.* Rīga: Zinātne, pp. 29—40.

Atgāzis, M. 1992. First finds of three-armed (threfoil) brooches in Latvia. *Die Kontakte zwischenOstbaltikum und Skandinavien im frühen Mittelalter: Internationale Konferenz 23.—25. Oktober 1990, Riga*. Studia Baltica Stockholmiensia, 9. Uppsala: p. 9.—32

Atgāzis, M. 2001. Vidējais dzelzs laikmets, 400.-800.g. [Middle Iron Age, 400-800 AD]. *In:* Apals, J., Atgāzis, M., Graudonis, J., Loze, I., Mugurēvičs, Ē., Vasks, A. & Zagorska, I. (eds.) *Latvijas senākā vēsture.* Riga: Latvijas vēstures institūta apgāds, pp. 232-289.

Atgāzis, M. 2019. Tuvcīņas ieroči Latvijā 10. – 13. gadsimtā. [Close combat weapons in Latvia in the 506 10th - 13th centuries AD], Riga, Latvijas vēstures institūta apgāds.

Banyté-Rowell, R., Buža, Z., Ciglis, J., Gariciuviené, E., Jarockis, R., Radiņš, A., Vasilauskas, E., Vaškevičiūte, I., Virse, L. & Žeiere, I. 2003. *Zemgaļi senatnē = Žiemgaliai senoje [Semigallians in Antiquity],* Rīga, N.I.M.S.

Barrett, J. H. & Richards, M. P. 2004. Identity, gender, religion and economy: new isotope and radiocarbon evidence for marine resource intensification in early historic Orkney, Scotland, UK. *European Journal of Archaeology,* 7**,** 249-271.

Barrett, J. H., Locker, A. M. & Roberts, C. M. 2004. 'Dark Age Economics' revisited: the English fish bone evidence AD 600-1600. *Antiquity,* 78**,** 618-636.

Beaumont, J. & Montgomery, J. 2016. The Great Irish Famine: identifying starvation in the tissues of victims using stable isotope analysis of bone and incremental dentine collagen. *PLoS One,* 11**,** e0160065.

Beaumont, J., Montgomery, J., Buckberry, J. & Jay, M. 2015. Infant mortality and isotopic complexity: new approaches to stress, maternal health, and weaning. *American Journal of Physical Anthropology,* 157**,** 441-457.

Bērziņš, V., Brinker, U., Klein, C., Lübke, H., Meadows, J., Rudzīte, M., Schmölcke, U., Stümpel, H. & Zagorska, I. 2014. New research at Riņņukalns, a Neolithic freshwater shell midden in northern Latvia. *Antiquity,* 88**,** 715-732.

Bliujienė, A., Skipitytė, R., Garbaras, A., Miliauskienė, Ž., Šapolaitė, J., Ežerinskis, Ž., Čeponkus, J., Masiulienė, I., Simčenka, E. & Minkevičius, K. 2020. The first data on the human diet in Late Roman and Early Migration period western Lithuania: Evidence from stable isotope, archaebotanical and zooarchaeological analyses. *Journal of Archaeological Science: Reports,* 33**,** 102545.

Brink, S. & Price, N. 2008. *The viking world*, Routledge.

Brown, T. A. & Brown, K. 2011. *Biomolecular archaeology: an introduction,* Chichester, John Wiley & Sons.

Buikstra, J. E. & Ubelaker, D. H. 1994. *Standards for data collection from human skeletal remains,* Fayetteville, AR, Archeological Survey Research Seminar Series 44

Carr, C. 1995. Mortuary practices: Their social, philosophical-religious, circumstantial, and physical determinants. Journal of Archaeological Method and Theory, 2, 105-200.

Chisholm, B. S., Nelson, D. E. & Schwarcz, H. P. 1982. Stable-carbon isotope ratios as a measure of marine versus terrestrial protein in ancient diets. *Science,* 216**,** 1131-1132.

Cocozza, C., Cirelli, E., Groß, M. *et al.* 2022. Presenting the *Compendium Isotoporum Medii Aevi*, a Multi-Isotope Database for Medieval Europe. *Sci Data* 9, 354. https://doi.org/10.1038/s41597-022-01462-8

DeWitte, S. N. , and Stojanowski, C. M. 2015. The osteological paradox 20 years later: Past perspectives, future directions. *Journal of Archaeological Research*, 23, 397–450.

Dufour, E., Bocherens, H. & Mariotti, A. 1999. Palaeodietary implications of isotopic variability in Eurasian lacustrine fish. *Journal of Archaeological Science,* 26**,** 617-627.

Eglīte, I. 2016. Lauksaimniecībā izmantojamās zemes valsts pārskata karte. *Agrozemes*, https://www.agrozemes.lv/, available Lauksaimniecībā izmantojamās zemes kvalitātes rādītāji

Eriksson, G. 2004. Part-time farmers or hard-core sealers? Västerbjers studied by means of stable isotope analysis. *Journal of Anthropological Archaeology,* 23**,** 135-162.

Eriksson, G. 2006. Stable isotope analysis of human and faunal remains from Zvejnieki. *In:* Larsson, L. & Zagorska, I. (eds.) *Back to the origin: New research in the Mesolithic-Neolithic Zvejnieki cemetery and environment, northern Latvia, Acta archaeologica Lundensia. Series in 8, (52).* pp.

Eriksson, G., Lõugas, L. & Zagorska, I. 2003. Stone Age hunter-fisher-gatherers at Zvejnieki, northern Latvia: radiocarbon, stable isotope and archaeozoology data. *Before farming,* 1**,** 1-26.

Etu-Sihvola, H., Salo, K., Naito, Y. I., Kytökari, M., Ohkouchi, N., Oinonen, M., Heyd, V. & Arppe, L. 2022. Isotopic insights into the early Medieval (600–1100 CE) diet in the Luistari cemetery at Eura, Finland. *Archaeological and Anthropological Sciences,* 14**,** 143.

Etu-Sihvola, H., Bocherens, H., Drucker, D.G., Junno, A., Mannermaa, K., M. Oinonen, M., Uusitalo, J., Arppe, L. 2019. The dIANA database – Resource for isotopic paleodietary research in the Baltic Sea areaJournal of Archaeological Science: Reports, 24, 1003-1013. https://doi.org/10.1016/j.jasrep.2019.03.005.

Fahy, G. E., Deter, C., Pitfield, R., Miszkiewicz, J. J. & Mahoney, P. 2017. Bone deep: Variation in stable isotope ratios and histomorphometric measurements of bone remodelling within adult humans. *Journal of Archaeological Science,* 87**,** 10-16.

Fazekas, I. G. & Kósa, F. 1978. *Forensic fetal osteology,* Budapest, Akadémiai Kiadó.

Fernandes, R. 2016. A Simple(R) Model to Predict the Source of Dietary Carbon in Individual Consumers. *Archaeometry*, 58, 500-512. doi:10.1111/arcm.12193

Fernandes, R., Nadeau, M.-J. & Grootes, P. 2012. Macronutrient-based model for dietary carbon routing in bone collagen and bioapatite. *Archaeological and Anthropological Sciences*, 4, 291-301. doi:10.1007/s12520-012-0102-7

Filipović, D., Meadows, J., Corso, M. D., Kirleis, W., Alsleben, A., Akeret, Ö., Bittmann, F., Bosi, G., Ciută, B., Dreslerová, D., Effenberger, H., Gyulai, F., Heiss, A. G., Hellmund, M., Jahns, S., Jakobitsch, T., Kapcia, M., Klooß, S., Kohler-Schneider, M., Kroll, H., Makarowicz, P., Marinova, E., Märkle, T., Medović, A., Mercuri, A. M., Mueller-Bieniek, A., Nisbet, R., Pashkevich, G., Perego, R., Pokorný, P., Pospieszny, Ł., Przybyła, M., Reed, K., Rennwanz, J., Stika, H.-P., Stobbe, A., Tolar, T., Wasylikowa, K., Wiethold, J. & Zerl, T. 2020. New AMS 14C dates track the arrival and spread of broomcorn millet cultivation and agricultural change in prehistoric Europe. *Scientific Reports,* 10**,** 13698.

Fogel, M. L., Tuross, N. & Owsley, D. W. 1989. Nitrogen isotope tracers of human lactation in modern and archaeological populations. *Carnegie Institution of Washington Yearbook,* 88**,** 111-117.

Fuller, B. T., Fuller, J. L., Sage, N. E., Harris, D. A., O'Connell, T. C. & Hedges, R. E. 2005. Nitrogen balance and δ15N: why you're not what you eat during nutritional stress. *Rapid Communications in Mass Spectrometry: An International Journal Devoted to the Rapid Dissemination of Up-to-the-Minute Research in Mass Spectrometry,* 19**,** 2497-2506.

Gerhards, G. 2002. Dažas dzelzs laikmeta pētniecības problēmas antropoloģiskā skatījumā [Some Iron - Age questions from an athropological perspective]. *Latvijas arheoloģija. Pētījumi un problēmas. Latvijas Vēstures Muzeja raksti, 8: Arheoloģija, numismātika, antropoloģija, paleobotānika.* – Rīga, 41. –52.

Guiry, E. J., & Szpak, P. 2021. Improved quality control criteria for stable carbon and nitrogen isotope measurements of ancient bone collagen. *Journal of Archaeological Science* 132, 105416. doi:10.1016/j.jas.2021.105416.

Guiry, E., 2019. Complexities of stable carbon and nitrogen isotope biogeochemistry in ancient freshwater ecosystems: Implications for the study of past subsistence and environmental change. *Frontiers in Ecology and Evolution*, 7, p.313.

Gunnarsone, A., Oras, E., Talbot, H. M., Ilves, K. & Legzdiņa, D. 2020. Cooking for the living and the dead: lipid analyses of Rauši settlement and cemetery pottery from the 11th - 13th century *Estonian Journal of Archaeology,* 24**,** 45-69.

Hedges, R. E. & Reynard, L. M. 2007. Nitrogen isotopes and the trophic level of humans in archaeology. *Journal of Archaeological Science,* 34**,** 1240-1251.

Hedges, R. E. M., Stevens, R. E. & Richards, M. P. 2004. Bone as a stable isotope archive for local climatic information. *Quaternary Science Reviews,* 23**,** 959-965.

Katzenberg, M. A. & Weber, A. 1999. Stable isotope ecology and palaeodiet in the Lake Baikal region of Siberia. *Journal of Archaeological Science,* 26**,** 651-659.

Katzenberg, M. A. 1989. Stable isotope analysis of archaeological faunal remains from southern Ontario. *Journal of Archaeological Science,* 16, 319-329.

Katzenberg, M. A. 2008. Stable Isotope Analysis: A Tool for Studying Past Diet, Demography, and Life History. *In:* Katzenberg, M. A. & Saunders, S. R. (eds.) *Biological Anthropology of the Human Skeleton.* 2nd ed., Hoboken, NJ: John Wiley & Sons, pp. 413-441.

Ķimsis, J., Petersone-Gordina, E., Poksane, A., Vilcāne, A., Moore, J., Gerhards, G. & Ranka, R. 2023. Application of natural sciences methodology in archaeological study of Iron Age burials in Latvia: pilot study. *Forensic Science, Medicine and Pathology,* 19(1), 8-15.

Kjellström, A., Storå, J., Possnert, G. & Linderholm, A. 2009. Dietary patterns and social structures in medieval Sigtuna, Sweden, as reflected in stable isotope values in human skeletal remains. *Journal of Archaeological Science,* 36, 2689-2699.

Kosiba, S. B., Tykot, R. H. & Carlsson, D. 2007. Stable isotopes as indicators of change in the food procurement and food preference of Viking Age and Early Christian populations on Gotland (Sweden). *Journal of Anthropological Archaeology,* 26, 394-411.

Legzdiņa, D., Vasks, A., Plankājs, E. & Zariņa, G. 2020. Re-evaluating the bronze and earliest iron age in Latvia: Changes in burial traditions in the light of ^{14}C dates. *Radiocarbon,* 62, 1845-1868.

Lightfoot, E., & O'Connell, T. C. 2016. On the use of biomineral oxygen isotope data to identify human migrants in the archaeological record: intra-sample variation, statistical methods and geographical considerations. PloS one, 11(4), e0153850.

Ligi, P. 1995. Ühiskondlikest oludest Eesti alal hilispronksi- ja rauaajal [Social Systems in Estonia during the Late Bronze and Iron Age]. *In:* Lang, V. (ed.) *Muinasaja teadus: Eesti arheoloogia historio-graafilisi, teoreetilisi ja kultuuriajaloolisi aspekte.* Tallinn: Ajaloo Instituut, pp. 182-270.

Linderholm, A., Jonson, C. H., Svensk, O. & Lidén, K. 2008. Diet and status in Birka: stable isotopes and grave goods compared. *antiquity,* 82**,** 446-461.

Lowry, R. 1998-2023. VassatStats: Website for Statistical Computation, http://vassarstats.net/index.html

Lübke, H., Brinker, U., Meadows, J., Bērziņš, V. & Zagorska, I. 2016. New research on the human burials of Riņņukalns, Latvia. *In:* Grünberg, J. & Gramsch, B. (eds.) *Mesolithic Burials – Rites, Symbols and Social Organization of Early Postglacial Communities, Proceedings of the International Conference, Halle (Saale), 18th–21st September 2013.* Sonderband: Archäologie in Sachsen-Anhalt, pp.

Lūsēns, M. 2012. Arheoloģiskie izrakumi Čunkānu - Dreņģeru senkapos 2010. gadā [Archaeological excavations in the Čunkāni-Dreņģeri cemetery in 2010]. *Arheologu pētījumi Latvijā 2010.–2011. gadā.* Rīga: Nordik, pp. 45-49.

Maresh, M. M. 1970. Measurements from roentgenograms. *In:* McCammon, R. W. (ed.) *Human growth and development.* Springfield, IL: Charles C Thomas, pp. 157-200.

Meadows, J., Bērziņš, V., Legzdiņa, D., Lübke, H., Schmölcke, U., Zagorska, I. & Zariņa, G. 2018. Stone-age subsistence strategies at Lake Burtnieks, Latvia. *Journal of Archaeological Science: Reports,* 17**,** 992-1006.

Moen, M. 2019. Gender and archaeology: where are we now? *Archaeologies,* 15**,** 206-226.

Mueller-Bieniek, A., Nowak, M., Styring, A., Lityńska-Zając, M., Moskal-del Hoyo, M., Sojka, A., Paszko, B., Tunia, K. & Bogaard, A. 2019. Spatial and temporal patterns in Neolithic and Bronze Age agriculture in Poland based on the stable carbon and nitrogen isotopic composition of cereal grains. *Journal of Archaeological Science: Reports,* 27**,** 101993.

Mugurēvičs, Ē. 1977. *Oliņkalna un Lokstenes pilsnovadi: 3.-15. gs. arheoloģiskie pieminekļi [Olinkalns and Lokstene: archaeological monuments from the 3rd - 15th centuries AD],* Riga, Zinātne.

Oras, E., Tõrv, M., Jonuks, T., Malve, M., Radini, A., Isaksson, S., Gledhill, A., Kekišev, O., Vahur, S. & Leito, I. 2018. Social food here and hereafter: Multiproxy analysis of gender-specific food consumption in conversion period inhumation cemetery at Kukruse, NE-Estonia. *Journal of Archaeological Science,* 97**,** 90-101.

Petersone-Gordina, E., Roberts, C. A., Millard, A. R., Montgomery, J. & Gerhards, G. 2018. Dental disease and dietary isotopes of individuals from St Gertrude Church cemetery, Riga, Latvia. *PLoS One,* 13**,** e0191757.

Pētersone-Gordina, E., Gerhards, G., Vilcāne, A., Millard, A. R., Moore, J., Ķimsis, J. & Ranka, R. 2022. Diet and social status in the Lejasbitēni Iron Age population from Latvia. *Journal of Archaeological Science: Reports,* 44**,** 103519.

Radiņš, A. 1999. 10. –13. gadsimta senkapi latgaļu apdzīvotajā teritorijā un Austrumlatvijas etniskās, sociālās un politiskās vēstures jautājumi [Ancient cemeteries from the 10th - 13th centuries AD in the Latgallian territories, and the ethnic, social, and political issues of the eastern Latvia]. *Latvijas Vēstures Muzeja raksti Nr. 5: Arheoloģija.* Rīga: N.I.M.S, pp.

Rasiņš, A. & Tauriņa, M. 1983. Pārskats par Latvijas PSR arheoloģiskajos izrakumos atrastajām kultūraugu un nezāļu sēklām [An overview of cultivar and weed seeds found during archaeological excavations in the Latvian SSR]. *Arheoloģija un etnogrāfija. –14. laid.*, 152–174.

Richards, M. P., Fuller, B. T. & Molleson, T. 2006. Stable isotope palaeodietary study of humans and fauna from the multi-period (Iron Age, Viking and Late Medieval) site of Newark Bay, Orkney. *Journal of Archaeological Science,* 33**,** 122-131.

Sellevold, B. J., Bröste, K., Hansen, U. L. & Jørgensen, J. B. 1984. *Iron age man in Denmark: Prehistoric man in Denmark*, Kongelige Nordiske Oldskrift-Selskab.

Seo, S. 2006. A review and comparison of methods for detecting outliers in univariate data sets. Doctoral Dissertation, University of Pittsburgh. Accessible at: http://d-scholarship.pitt.edu/7948/2006.

Simčenka, E., Kozakaitė, J., Piličiauskienė, G., Gaižauskas, L. and Piličiauskas, G., 2022. Human diet during the Stone Age and Early Metal Period (7000–1 CAL BC) in Lithuania: an update. *Radiocarbon*, pp.1-19.

Sloka, J. 1979. Zivis senajās X – XIV gadsimta apmetnēs Daugavas krastos [Fish in the ancient 10th - 14th century settlements on the banks of river Daugava]. *Latvijas PSR Zinātņu Akadēmijas Vēstis,* 9**,** 131-134.

Sloka, J. 1986. Zivis Tērvetes pilskalnā [Dobeles rajons] (X-XIII gs.) un Mežotnes pilskalnā [Bauskas rajons] (XI-XII gs.) [Fish in the Tērvete hillfort (10th - 13th centuries AD) and the Mežotne hillfort (11th - 12th centuries AD)]. *Latvijas PSR Zinātņu Akadēmijas Vēstis,* 9**,** 51-67.

Steele, K. & Daniel, R. M. 1978. Fractionation of nitrogen isotopes by animals: a further complication to the use of variations in the natural abundance of 15 N for tracer studies. *The Journal of Agricultural Science,* 90**,** 7-9.

Šnē, A. 2002. *Sabiedrība un vara: Sociālās attiecības Austrumlatvijā aizvēstures beigās [Society and power: social relations in eastern Latvia in the end of prehistory],* Rīga, Intelekts.

Tautavičius, A. 1996. *Vidurinis geležies amžius Lietuvoje (V-IX a.) [Middle Iron Age in Lithuania (5th-9th centuries AD)]* Vilnius, Pilių tyrimo centras „Lietuvos pilys".

Van Klinken, G.-J. 1999. Bone Collagen Quality Indicators for Palaeodietary and Radiocarbon Measurements. *Journal of Archaeological Science* 26, 687-695. doi:10.1006/jasc.1998.0385.

Vasks, A. & Zariņa, G. 2014. Ķivutkalns hill-fort and cemetery: New data and new problems. *Journal of the Institute of Latvian History/Latvijas Vēstures Institūta Žurnāls*, 3(92), 5-36.

Vasks, A. 2018. The Pre-History of Latvia (10500 BCE - 1200 CE) *Latvia and Latvians: Collection of scholarly articles, Vol. 2, Part 3.* Rīga: Latvian Academy of Sciences, pp. 9-39.

Vasks., A. 2016. Arheoloģija Latvijā pēc Otrā pasaules kara (līdz 1990. gadam) [Latvian Archaeology after World II (up to 1990)], *Journal of the Institute of Latvian History/Latvijas Vēstures Institūta Žurnāls*, 3(100), 7-66.

Vaškevičiūtė, I. 2004. *Žiemgaliai V-XII amžiuje,* Vilnius: Vilniaus pedagoginio universiteto leidykla, pp. 22.

Webb, E. C., Honch, N. V., Dunn, P. J. H., Eriksson, G., Lidén, K. & Evershed, R. P. 2015. Compound-specific amino acid isotopic proxies for detecting freshwater resource consumption. *Journal of Archaeological Science,* 63**,** 104-114.

Whitmore, K. M., Dupras, T. L., Williams, L. J., Skipitytė, R., Schultz, J. J. & Jankauskas, R. 2019. Stable carbon and nitrogen isotope inter-and intra-individual dietary reconstruction from the late 14th to early 18th century site of Alytus, Lithuania. *American journal of physical anthropology,* 168**,** 279-291.

Zagorska, I. 2006. Radiocarbon chronology of the Zvejnieki burials. *Acta archaeologica Lundensia. Series in 8***,** 91-113.

Zariņa, G. 2016. *Ikšķiles 13.–15. gadsimta iedzīvotāji [13th–15th century population of Ikšķile],* Riga, Zinātne

Supplementary Information A

Table 1S List of ^{14}C dates of human bone samples from Čunkāni – Drenģeri cemetery. All dates were obtained during the current research. The dates were calibrated by OxCal v4.4.2 (Bronk Ramsey 2009) using IntCal20 (Reimer et al. 2020) and are reported with ranges rounded out to the next 5 years (Millard 2014)

No.	Burial*	Sample	Lab no.**	14C age (BP)	Cal CE (68.3%)	Cal CE (95.4%)
1	43	Bone	Poz-136709	1085 ± 30	895 (24.4%) 925 CE 950 (41.1%) 995 CE 1005 (2.8%) 1015 CE	890 (95.4%) 1025 CE
2	241	Bone	Poz-117809	1280 ± 30	675 (40.8%) 710 CE 720 (27.4%) 775 CE	660 (90.8%) 780 CE 790 (4.7%) 820 CE
3	294	Bone	Poz-136755	1310 ± 30	660 (29.2%) 690 CE 695 (3.2%) 705 CE 740 (35.9%) 775 CE	655 (95.4%) 775 CE
4	316	Bone	Poz-136757	1195 ± 30	775 (10.0%) 795 CE 800 (4.5%) 810 CE 820 (53.7%) 885 CE	705 (2.9%) 730 CE 770 (88.6%) 895 CE 920 (4.0%) 950 CE
5	351d	Bone	Poz-117609	1150 ± 30	775 (4.8%) 785 CE 830 (5.4%) 850 CE 875 (17.7%) 905 CE 915 (40.3%) 925 CE	770 (7.5%) 790 CE 820 (88.0%) 990 CE
6	380	Bone	Poz-117610	1370 ± 30	640 (68.3%) 675 CE	600 (88.6%) 685 CE 740 (5.7%) 760 CE 765 (1.2%) 775 CE

*Archaeological context information given as it appears in primary documentation and/or publications

**Laboratory code "Poz" = Poznan Radiocarbon Laboratory, Poland

References

Bronk Ramsey, C. 2009. Bayesian analysis of radiocarbon dates. *Radiocarbon* 51, 337–360.

Millard, A. R. 2014. Conventions for reporting radiocarbon determinations. *Radiocarbon* 56, 555-559. doi: 10.2458/56.17455.

Reimer, P., Austin, W., Bard, E., Bayliss, A., Blackwell, P., Bronk Ramsey, C., Butzin, M., Cheng, H., Edwards, R., Friedrich, M., Grootes, P., Guilderson, T., Hajdas, I., Heaton, T., Hogg, A., Hughen, K., Kromer, B., Manning, S., Muscheler, R., Palmer, J., Pearson, C., van der Plicht, J., Reimer, R., Richards, D., Scott, E., Southon, J., Turney, C., Wacker, L., Adolphi, F., Büntgen, U., Capano, M., Fahrni, S., Fogtmann-Schulz, A., Friedrich, R., Köhler, P., Kudsk, S., Miyake, F., Olsen, J., Reinig, F., Sakamoto, M., Sookdeo, A., & Talamo, S. 2020. The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0–55 cal kBP). *Radiocarbon*, 62, 725-757. doi:10.1017/RDC.2020.41.

Supplementary Information B

Initial sample preparation and collagen extraction was carried out in the Archaeological Isotope and Peptide Research Laboratory (AIPRL), Durham University where all samples were cleaned and abraded using a tungsten carbide dental drill to remove surface contamination. Collagen extraction was carried out following the procedure outlined in O'Connell and Hedges (1999). Approximately 300mg of cleaned bone was demineralised in 0.5M HCl at 4°C for several days then rinsed thoroughly in ultra-pure water (18.2MΩ·cm). Following this, samples were gelatinised in a pH 3 solution of HCl at 70°C for 48 hours, after which insoluble residues were removed using Ezee® filters. The filtered samples were then frozen at -18°C and freeze dried for 48 hours, the resultant collagen was then weighed into tin capsules. Stable isotope analysis was carried out in the Stable Isotope Biogeochemistry Laboratory (SIBL), Durham University using a Thermo Scientific Delta V Advantage isotope ratio mass spectrometer. Calibration using internal reference samples (e.g., Glutamic Acid, Glycine, SPAR and Urea) and international reference standards (e.g., USGS 24, USGS 40, IAEA 600, IAEA N1, IAEA N2) determined a standard deviation of ±0.1‰ (1σ) for collagen carbon and nitrogen isotopes.

Supplementary Information C

Table 2S Mean $\delta^{15}N$ and $\delta^{13}C$ values of comparative cemetery populations from Latvia

Site	N	$\delta^{15}N$	SD	$\delta^{13}C$	SD	Reference
Zvejnieki	37	12.22	1.14	-22.90	1.10	Eriksson et al. 2003; Eriksson 2006; Meadows et al. 2018; Lübke et al. 2016; Bērziņš et al. 2014; Zagorska 2006
Riņņukalns	3	12.17	0.57	-24.30	0.79	Lübke et al. 2016; Bērziņš et al. 2014
Ķivutkalns	13	10.33	0.60	-19.87	0.82	Vasks and Zariņa 2014
Reznes	6	10.60	0.49	-20.33	1.10	Legzdiņa et al. 2020
Lejasbitēni	29	9.90	0.74	-22.66	0.46	Petersone-Gordina et al. 2022
Ikšķile	7	11.21	1.23	-20.61	0.42	Zariņa 2016
Rīga	96	11.11	0.89	-20.36	0.46	Petersone-Gordina et al. 2018
Jelgava	7	14.09	0.70	-19.97	0.33	

References

Bērziņš, V., Brinker, U., Klein, C., Lübke, H., Meadows, J., Rudzīte, M., Schmölcke, U., Stümpel, H. & Zagorska, I. 2014. New research at Riņņukalns, a Neolithic freshwater shell midden in northern Latvia. *Antiquity,* 88**,** 715-732.

Eriksson, G. 2006. Stable isotope analysis of human and faunal remains from Zvejnieki. *In:* Larsson, L. & Zagorska, I. (eds.) *Back to the origin: New research in the*

Mesolithic-Neolithic Zvejnieki cemetery and environment, northern Latvia, Acta archaeologica Lundensia. Series in 8, (52). pp.

Eriksson, G., Lõugas, L. & Zagorska, I. 2003. Stone Age hunter-fisher-gatherers at Zvejnieki, northern Latvia: radiocarbon, stable isotope and archaeozoology data. *Before farming,* 1**,** 1-26.

Legzdiņa, D., Vasks, A., Plankājs, E. & Zariņa, G. 2020. Re-evaluating the bronze and earliest iron age in Latvia: Changes in burial traditions in the light of ^{14}C dates. *Radiocarbon,* 62**,** 1845-1868.

Lübke, H., Brinker, U., Meadows, J., Bērziņš, V. & Zagorska, I. 2016. New research on the human burials of Riņņukalns, Latvia. *In:* Grünberg, J. & Gramsch, B. (eds.) *Mesolithic Burials – Rites, Symbols and Social Organization of Early Postglacial Communities, Proceedings of the International Conference, Halle (Saale), 18th–21st September 2013.* Sonderband: Archäologie in Sachsen-Anhalt, pp.

Meadows, J., Bērziņš, V., Legzdiņa, D., Lübke, H., Schmölcke, U., Zagorska, I. & Zariņa, G. 2018. Stone-age subsistence strategies at Lake Burtnieks, Latvia. *Journal of Archaeological Science: Reports,* 17**,** 992-1006.

Petersone-Gordina, E., Roberts, C. A., Millard, A. R., Montgomery, J. & Gerhards, G. 2018. Dental disease and dietary isotopes of individuals from St Gertrude Church cemetery, Riga, Latvia. *PLoS One,* 13**,** e0191757.

Pētersone-Gordina, E., Gerhards, G., Vilcāne, A., Millard, A. R., Moore, J., Ķimsis, J. & Ranka, R. 2022. Diet and social status in the Lejasbitēni Iron Age population from Latvia. *Journal of Archaeological Science: Reports,* 44**,** 103519.

Vasks, A. & Zariņa, G. 2014. Ķivutkalns hill-fort and cemetery: New data and new problems. *Journal of the Institute of Latvian History/Latvijas Vēstures Institūta Žurnāls*, 3(92), 5-36.

Zagorska, I. 2006. Radiocarbon chronology of the Zvejnieki burials. *Acta archaeologica Lundensia. Series in 8***,** 91-113.

Zariņa, G. 2016. *Ikšķiles 13.–15. gadsimta iedzīvotāji [13th–15th century population of Ikšķile],* Riga, Zinātne.

Supplementary Figure

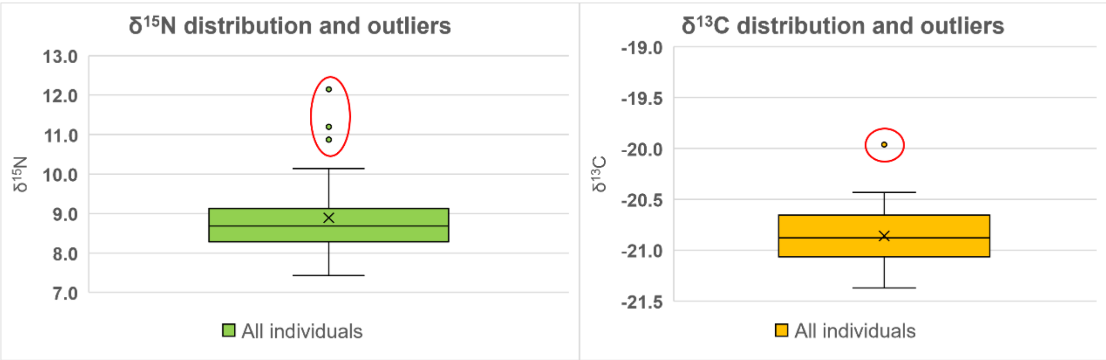

Fig. 1S Box plots showing the distribution of δ^{13}C and δ^{15}N values, and isotopic outliers in the Čunkāni-Dreņģeri population (N=29)