



Childhood in the Carpathians: An isotopic analysis of childhood diet and weaning in a medieval and Early Modern Transylvanian village

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ABSTRACT

In this article, we explore aspects of daily life through the lens of non-adult diet in the High and Late Medieval (1000–1500 CE) and Early Modern (1500–1800 CE) periods using skeletons from a church cemetery located in Mugeni (Bögöz in Hungarian), Romania. Carbon and nitrogen isotope analysis was conducted on dentin collagen samples from 20 non-adults as well as bone collagen from 3 non-adults. The mean dentin $\delta^{13}\text{C}$ ($-18.4\text{‰} \pm 1.7\text{‰}$) and $\delta^{15}\text{N}$ ($12.5\text{‰} \pm 1.2\text{‰}$) measurements reveal a variable overall non-adult diet consisting primarily of terrestrial proteins and the use of both C_3 and C_4 grains to varying degrees. An average decrease in nitrogen values over the non-adult life course additionally provides context on the weaning process and other dietary changes.

1. Introduction

For most of the High and Late Medieval (1000–1500 CE) and Early Modern periods (1500–1800 CE), Transylvania was an eastern political territory of Hungary until it became part of Romania in 1918 (Hitchins, 1979). This study is concerned with a skeletal assemblage excavated from a church cemetery in the present-day Transylvanian village of Mugeni (Bögöz in Hungarian) that was in use from 1100 to 1800 CE. Historically and today, the study's region in the eastern basin of the Carpathian Mountains was home to an ethno-culture known as the Székely. This region is now known as the Székelyföld in the local Hungarian language and was the eastern border of the Hungarian Kingdom during the Medieval period. The time-frame of the church cemetery includes several politically important periods in Transylvanian history, including the Hungarian rule of Transylvania (900–1526 CE), the Reformation during the 1500 s CE, semi-independent statehood under Ottoman rule in 1540 CE, and formation of a principality of the Austro-Hungarian Empire (1711–1867 CE) (Barta et al., 1994; Borcoman, 2009; Gündisch, 1998; Murdock, 2000). Additionally, this region of Transylvania was frequently invaded, including by the Ottoman Empire (Barta et al., 1994; Murdock, 2000). Székely males of various classes were often tasked with fighting and defending the eastern Hun-

garian border against these invasions, often leaving their families behind (Sófalvi, 2013). This frequent historical unrest had the potential to disrupt the lives of those in these communities, which may have impacted child-rearing practices in the local villages. Because of its geographical location and its history of invasions, the region may have also become a cultural melting pot (Murdock, 2000). Little is known, however, about how that may have influenced local gastronomy and farming practices, or whether dietary resources were apportioned differently to men, women, weaning infants, and growing children.

Information about the lives of infants and children in this time and place comes primarily from the archaeological record. In a church cemetery roughly 70 km away from Bögöz, in Teleac (Telekfalva in Hungarian), Transylvania, archaeologists excavated 70 graves dating to the seventeenth century; of these burials, 69 were those of non-adults and 70% were the skeletons of neonates (Bethard et al., 2019). In another church cemetery in Văleni (Patakfalva in Hungarian), every analyzed perinatal or preterm skeleton had nonspecific periosteal reactions potentially related to nutritional deficiencies such as scurvy or rickets (Bethard et al., 2019; Osterholtz et al., 2014). These forms of pathology are often related to weaning stress on non-adult skeletons (Lewis, 2007). Dental disease has also been found in non-adult skeletons from this region (Rothwell et al., 2015).

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Surviving texts from Transylvania are rare from the medieval period, due to religious and political events in the region such as the Reformation and invasions (Papahagi 2015); however, some surviving texts from the Early Modern period are helpful in better understanding the lives of non-adults in Transylvania. For example, parish registers from two Székely villages provide a glimpse into infant mortality in the region; Pakot (2015) reports that roughly 21% of infants under 1 year of age died during the Early Modern period in these villages.

Although there are few surviving primary texts about the dietary recommendations for children in the Székelyföld, animal husbandry and agricultural practices are able to be gleaned from village laws dated from 1581 to 1847 (Molnár et al., 2015) that elucidate the overall resources in the region. Historic village laws from the Székelyföld suggest that wheat was the most commonly cultivated cereal grain; however, the other two major crops were barley and oats (Molnár et al., 2015). Archaeological work at sites in Romania and Hungary (Gyulai, 2010, 2014a, 2014b; Szűcs, 2002) complements information gleaned from village laws in terms of animal husbandry, cereal grain cultivation, and fruit domesticates. High concentrations of common bread wheat, along with six-rowed barley and other grains (Gyulai, 2014b) were found at archaeological excavations from two neighboring medieval sites in Hungary and millet has been found at medieval sites throughout Hungary (Gyulai, 2014a). It appears that people in this region primarily consumed wheat, as well as barley and millet to a lesser extent.

Aside from these major crops, the Székely also grew “poppy, pea, maize, oats, barley, onion, cabbage, potato, hemp, lentil, squash, and fodder beet” (Molnár et al., 2015, p. 21). Domesticated fruit trees and vines (apples, grapes, cherries, and pear) and wild fruits from nearby forests were also a likely component of the Székely diet. Székely villagers living close to forests would likely have foraged for wild fruits, fungi, and medicinal herbs, and even hunted for wild game, as wolf and bear hunting was revered and celebrated. Animal husbandry of various bovines, equines, and suids is often cited in the village laws, and these animals would graze the fallow fields (Molnár et al., 2015). From these village laws, we also know fodder was rarely produced for animal consumption in this part of Transylvania. However, texts from a later time period suggest that cows were fed dry fodder (i.e., hay, grain) when the milk was for a weaning infant to avoid stomach upset (Dumănescu, 2009); this practice may have also been the case during the medieval or Early Modern periods. Pigs, sheep, and goats were consumed as meat or used for their milk; and cows are most often cited as “milk cows.” Medieval Hungarian settlements were usually located near riverbanks, and in the Early Medieval period, these settlements likely had artificial lakes full of fish, as a result of participation in the Catholic dietary practices, such as Lent or Friday fasting (Rabb, 2007). The dietary reliance on fish, however, may have decreased in later centuries because of a large-scale conversion from Catholicism to Calvinism in Hungary and Transylvania between the 17th and 18th centuries (Murdock, 2000). Regardless, children were often exempt from the Catholic fasting laws in Medieval Europe (Adamson, 2004). Additionally, village laws in the Székelyföld mention freshwater fish, but the practice of fishing in village water sources was heavily regulated (Molnár et al., 2015). The geographical and historical evidence therefore tells us that people in these villages likely ate beef and pork for protein, consumed dairy products, and occasionally included wild game and freshwater fish. In the absence of specific records of the non-adult diet in this region, we can look to previous research in Europe during the medieval period for clues. Infants under the age of 3 were more commonly fed breast milk and/or weaning resources such as easily digestible, cooked grains (Adamson, 2004; Fulminante, 2015; Orme, 2003; Wickes, 1953). Children began consuming traditional adult foods between the ages of 6–10 (Adamson, 2004). However, much of what we know comes from Western and Central Europe, and these recommendations may not have been practiced in Eastern Europe.

The bioarchaeological analyses of non-adults, as well as the historical events that transpired (i.e., invasions, political changes) in this region of the world during the Early Modern and medieval periods raise questions about the experiences of young Székely villagers during a liminal period in life when individuals are dependent on their caretaker (s) for their overall health and survival. Diet has an influential role in the survival and health of non-adults and, therefore, the present study seeks to investigate weaning practices and the dietary breadth of non-adults from a Székely village during the medieval and Early Modern period.

1.1. Dietary reconstruction using stable isotope analysis

Stable isotope analysis has become standard within bioarchaeology because of its relative importance in observing dietary trends and migration patterns of past populations (Katzenberg, 2008; Makarewicz and Sealy, 2015). These isotopes are stable because they do not undergo radioactive decay and are therefore useful for discovering past diets and migration (Katzenberg, 2008; Mays, 1998). Stable isotope analysis is particularly useful when studying the dietary patterns of non-adults, particularly breastfeeding and weaning. When trying to understand dietary transitions during the early life course, breastfeeding and weaning are key, as they differ across cultures in terms of whether an infant should be breastfed, how long breastfeeding lasts, who feeds the infant, and when and with what resources weaning should occur (Britton et al., 2018; Fulminante, 2015; Woolridge, 1995). As a result, we use stable carbon and nitrogen isotope analysis and contextualized bioarchaeological data to understand what role the available resources played in non-adult diets and to better understand the weaning practices in the population.

Nitrogen isotope analysis is important for understanding the average duration of breastfeeding in past populations because of the trophic effect that occurs when infants consume breast milk (Fogel et al., 1989; Fuller et al., 2006; Katzenberg, 2008; Tsutaya and Yoneda, 2013, 2015). Neonates will typically exhibit nitrogen values similar to their mothers; however, as they begin solely consuming human milk protein, the infant’s nitrogen signature is raised by an average of 2–3‰ when compared with the adult female population, indicating a trophic shift (DeNiro and Epstein, 1981; Katzenberg, 2008; Mays et al., 2002; Schoeninger and Moore, 1992). When breastfeeding is progressively reduced by slowly integrating solid foods into the diet, this is known as the weaning process (Katzenberg et al., 1996). By observing decreasing nitrogen values through early life, it is possible to trace patterns of weaning (Britton et al., 2018; Fuller et al., 2006; Tsutaya and Yoneda, 2013, 2015; Tsutaya et al., 2015; Tsutaya, 2017). Overall, for human terrestrial based diets, a typical $\delta^{15}\text{N}$ falls between 6 and 12‰ (Pollard and Heron, 2008); because of the extended food chain, a marine based diet can exhibit $\delta^{15}\text{N}$ as high as 20‰ (Jay and Richards, 2006; Lightfoot et al., 2012; Richards and Hedges, 1999; Schoeninger and DeNiro, 1984; Triantaphyllou et al., 2008).

When analyzing non-adult diets isotopically, measuring stable carbon isotopes may be useful as an addition to nitrogen stable isotope analysis. Exclusively breastfed infants also exhibit a smaller trophic shift of 1‰ in $\delta^{13}\text{C}$ values; however, these values decline rapidly during the weaning process (Fuller et al., 2006). Carbon isotope analysis may also be used to discern when grain-based solid foods were introduced into an infant’s diet during the weaning process and to determine the composition of the non-adult diet after being fully weaned, particularly in terms of the C_3 (i.e., wheat, barley, legumes, nuts, and tubers) or C_4 (i.e., sorghum, millet, and maize) photosynthetic pathways. As a result of fractionation, overall $\delta^{13}\text{C}$ values of humans living in Europe average around -20‰ when predominantly consuming terrestrial C_3 resources and around -12‰ when predominantly consuming terrestrial and marine C_4 resources (Lightfoot et al., 2012; Martin et al., 2013; Schoeninger et al., 1983; Triantaphyllou et al., 2008).

Generally, isotopic analyses of past populations have been conducted on bulk collagen and, less frequently, hydroxyapatite from bone. However, using bone collagen has its limitations, particularly due to the great variability in bone remodeling rates, especially for skeletal elements of non-adults (Howcroft et al., 2014; Koo, 1996; Valentin, 1995). One method to combat this issue is analyzing primary dentin from teeth, which is found on both the root and crown of the tooth. Dentin is an avascular organic tissue that does not remodel like bone collagen does, but can provide precise windows into diet, with a measurable daily growth of 1.3 to 1.5 μm (Beaumont et al., 2013). Dentin therefore serves as an important alternative to bone collagen for stable isotope analysis of non-adult diet through time.

Few paleodietary analyses have been conducted on populations in the Carpathian Basin and modern-day Hungary, yet their findings have begun to elucidate dietary trends concerned with different ethnic groups from various eras (Crowder, 2019; Gíblin and Yerkes, 2016; Gugora et al., 2018; Sylva, 2014). From the Copper Age (3500 to 2300 BCE) to the medieval period (13th century CE), it appears people in the Carpathians and Great Hungarian Plain were consuming both terrestrial animal proteins and C_3 resources, with varying degrees of C_4 grains included in their diet, directly or indirectly. Several bioarchaeological analyses have been conducted on medieval Székely cemetery populations (Bailey et al., 2016; Bethard et al., 2014a, 2014b, 2016; Osterholtz et al., 2014; Peschel et al., 2017; Riegiert et al., 2014; Rothwell et al., 2015; Stuck et al., 2014). However, only one paleodietary study using stable isotopes has been conducted on the skeletal assemblage from Bögöz (Peschel et al. 2017). Using dentin collagen from 36 teeth and enamel carbonate from 10 teeth of 22 adults and 4 non-adults, Peschel and colleagues found that the sample population tested from the Bögöz assemblage primarily consumed C_3 plants or grains, as well as a small amount of C_4 resources, likely foxtail millet (*Setaria italica*) or broomcorn millet (*Panicum miliaceum*). This evidence makes sense in light of the ethnohistoric information that suggests the top three cereal grains produced in Székely villages were wheat, barley, and oats, which are all C_3 resources. Peschel and colleagues (2017) also found that most of the dietary protein came from C_3 -fed domesticated animals, and they concluded that pork was a staple animal protein in Transylvania since the Bronze Age. Further, these researchers determined that there was evidence of a dietary shift from the earlier inhabitants of the cemetery (e.g., 1300–1400 CE), which they hypothesized was due to social turmoil (i.e., Mongolian invasions, Hungarian invasions, and Saxon colonization) and climatic changes associated with the time period. They did not find age or sex related differences in their results; however, the results of the 4 non-adults were not further explored through the lens of childhood diet.

Based on the previous research regarding the overall diet of village residents in medieval and early modern Bögöz, we expand the paleodietary isotope work to learn more about cultural practices surrounding the diet of non-adults from this skeletal assemblage. Due to Transylvania's geographic location at a crossroads between Europe and Asia, as well as frequent colonization and invasions in the area, there is a possibility the weaning practices and the childhood diet may be different from the findings in Central and Western Europe, which suggest total weaning occurred by 2–3 during the medieval period and before age 2 in European cities during the Early Modern period (Britton et al., 2018; Burt, 2013; Dittmann and Grupe, 2000; Richards and Fuller, 2002). We hypothesize that, due to known trophic differences associated with breastfeeding, samples associated with young non-adults will exhibit higher nitrogen values than the rest of the tested population, whereas samples associated with older non-adults will exhibit similar paleodietary values to the adults from the previous study (Peschel et al., 2017).

Eastern Europe, and the Carpathian basin in particular, does not have as extensive a base of historical records as Western Europe due to the political climate of the past century, which resulted in destruction of texts (Mordock, 2000; Papahagi, 2015). Bioarchaeological studies

have been undertaken in recent years to fill in these historical gaps, particularly in Hungary and Transylvania (Crowder et al., 2019; Gugora et al., 2018). To date, no studies have examined medieval or early modern weaning in Székely communities despite interest in infant feeding practices in Europe across time (Britton et al., 2018; Fulminante, 2015; Haydock et al., 2013). This research is therefore the first to use stable isotope analysis to learn more about non-adult diets in the easternmost region of the former Kingdom of Hungary, in Székelyföld, Transylvania.

2. Materials and methods

The samples used in the present study come from non-adult skeletons excavated from the formerly Catholic, reformed Calvinist church cemetery in the village of Mugeni (Bögöz in Hungarian), Harghita County, Romania (Fig. 1). This village is located in the eastern Carpathian basin in Transylvania, roughly 180 miles from Bucharest, and is situated near the Târnava Mare river (Küküllő river). Archaeological excavation was led by Zolt Nyárádi in 2012–2013, subsequent to a preliminary excavation in 2009; both excavations were necessary as a result of church renovations. Radiocarbon dating has not yet been conducted on this skeletal assemblage. However, the cemetery was able to be dated to 1100–1800 CE based on the stratigraphic location of reconstruction materials for the church (when paired with historical texts) as well as coffin hardware and cultural materials (i.e., hair rings, coins, boot fittings). People buried in the Bögöz reformed church cemetery therefore lived during three major periods in European history: the High Medieval period (1000–1250 CE), the Late Medieval period (1250–1500 CE), and the Early Modern period (1500–1800 CE).

Of the 225 skeletons discovered in the cemetery, 59 were non-adults (Nyárádi, 2013). Bones and teeth from the excavated non-adult skeletons in Bögöz were collected and transported to the University of South Florida, where 20 tooth samples were chosen for analysis based on the presence of multiple deciduous and permanent teeth, the macroscopic appearance of preservation, stage of root formation, and the lack of evidence of carious lesions. Table 1 lists the dentition selected for analysis. Tooth roots were selected as the tissue to be analyzed because they contain substantially more dentin than the crown, which consists pri-



Fig. 1. Map of Romania showing location of Mugeni (Bögöz). Base map in the public domain via Wikimedia Commons, with border countries, major cities, and archaeological sites added.

Table 1Non-Adult $\delta^{13}\text{C}_{\text{co}}$ and $\delta^{15}\text{N}_{\text{co}}$ results from Bögöz, Transylvania. Tooth development stages are from Al Qahtani et al. (2010).

Skeleton	Tissue Used	Development Stage	Sex	Age at Death (years)	Time Period (CE)	$\delta^{13}\text{C}(\text{‰ VPDB})$	$\delta^{15}\text{N}(\text{‰ AIR})$	Collagen Yield (%)	C:N
005	Rc ¹	R 3/4	I	3.5–5.5	1500	−19.6	12.6	10.5	3.2
011	Rm ₂	R 3/4	I	3–5	1100–1200	−18.4	13.3	3.6	3.3
039	Rm ²	Rc	I	3–5	1500	−19.6	12.4	9.7	3.3
053	Ri ¹	Ac	I	12.5–14	1800	−15.6	12.6	15.5	3.2
059	Li ¹	Rc	I	15–17	1300–1400	−19.4	12.4	8.2	3.3
065	Li ¹	R 3/4	I	1–2	1700–1800	−12.6	13.7	16.0	3.2
085	LM ₁	Rc	I	7.5–9	1700	−18.3	12.6	17.0	3.2
102	RM ¹	Rc	I	7.5–9.5	1500	−19.0	11.4	8.2	3.2
107	Lm ¹	R 3/4	I	1.5–2.5	1600–1700	−18.1	14.0	26.5	3.2
108	Rm ¹	R 3/4	I	2–4	1600–1700	−16.3	13.9	19.8	3.2
109	Rm ²	R 3/4	I	2–4	1300	−19.4	11.8	12.4	3.2
115 ^{a,b}	Centrum	–	I	36–38 wks	1600–1700	−19.0	13.3	100.0	3.3
139	RM ²	Rc	F	9–15	1500–1600	−19.6	11.9	3.8	3.3
144	RM ₂	Rc	F	15–18	1500–1600	−19.6	11.9	12.2	3.2
158 ^b	Centrum	–	I	38–40 wks	1500–1600	−18.6	11.8	7.4	3.3
201	RM ¹	Ac	I	9–11	1500	−19.4	11.8	11.6	3.2
247 ^b	Rib	–	I	1.5–2	1300–1400	−17.6	14.6	7.7	3.2
257	Lm ₁	Ac	I	9.5–11.5	1200–1300	−19.0	12.4	16.4	3.2
275	RM ¹	R 3/4	I	6.5–8	1100	−19.6	10.9	7.9	3.3
279	Rm ²	R 3/4	I	3–5	1200–1300	−18.6	12.4	6.3	3.2
280	Li ¹	R 1/2	I	0.4–0.9	1200–1300	−17.9	15.2	3.1	3.4
281	Rm ²	Ac	I	5–6	1200–1300	−19.3	10.2	7.1	3.3
285	Lm ₁	Rc	I	3–5	1200–1300	−18.2	13.5	4.4	3.3

^a Anomalous collagen yield: removed from statistical analysis.^b Not used in statistical analyses.

marily of hydroxyapatite crystallites (Katzenberg, 2008). Due to the lack of preserved dentition in three non-adults, 2 vertebral centra and 1 rib were also sampled; however, these will not be included in the statistical analysis or discussion due to the difference in preservation between bone collagen and dentin collagen. The vertebral centra were from two individuals who died at 36–38 weeks (Skeleton 115) and 38–40 weeks (Skeleton 158), and the rib was from an individual whose age at death was estimated to be between 1.5 and 2 years (Skeleton 247). Limited testable samples were brought to the University of South Florida from Romania; the rib was selected because it has been found to be useful when assessing weaning practices (Nitsch et al. 2011) and vertebral centra were sampled because of a lack of other more substantive elements (i.e., rib, long bones).

Demographic analyses were conducted by supervised bioarchaeology field school students at a field lab facility in Odorheiu Secuiesc, Transylvania, in 2015. To assess dental development and age-at-death, Ubelaker (1999), Standards (Buikstra and Ubelaker, 1994) and the London Atlas (Al Qahtani et al., 2010) were used. Age-related skeletal changes were recorded using the methods of Scheuer and Black (2000), Fazekas and Kosa (1978), Gindhart (1973), Maresh (1970), Ogden (1984), and Schaefer and colleagues (2009). As no widely accepted sex estimation method exists for non-adult skeletons without the use of DNA, sex was estimated only for the oldest two individuals in the sampled assemblage using Buikstra and Ubelaker (1994), Kiales et al. (2012), and Phenice (1969). The overall sample population ($n = 23$) consists of two perinates of an estimated age range of 36–38 weeks and 38–40 weeks, and 21 non-adults who were 18 years of age or younger when they died. Table 1 lists the age at death estimates for the 23 individuals along with the root development stages for 20 individuals from whom dentin samples were obtained, per Al Qahtani et al. (2010).

Tooth roots were bisected from the crown at the cemento-enamel junction prior to the collagen extraction process. Dentin and bone collagen extraction procedures followed those laid out by Ambrose (1990) and modified by Tykot (2004), Tykot (2020). All samples were soaked in 50 mL 0.1 M sodium hydroxide (NaOH) solution for a period of 24 h to remove base-soluble contaminants. After rinsing with ddH₂O to remove the NaOH solution, 50 mL of a solution of 2% HCl was used to remove the hydroxyapatite portion through soaking for at least 72 h with daily replacement of the HCl solution. The samples were again

treated with 50 mL of 0.1 M NaOH for a period of 24 h to remove humic acids and subsequently poured off with distilled water. A defatting mixture of 2:1:0.8 CH₃OH : CHCl₃ : ddH₂O was used to remove lipids from the demineralized and decontaminated samples. A ThermoFisher Scientific Delta V Advantage Isotope Ratio Mass Spectrometer was used to analyze the dried, weighed samples at the University of South Florida College of Marine Science Stable Isotope Ratio Mass Spectrometry Facility. All samples were run in duplicate with reported standard deviations of $\pm 0.14\text{‰}$ for $\delta^{13}\text{C}$ and $\pm 0.11\text{‰}$ for $\delta^{15}\text{N}$. The NIST 8573 and 8574 standards were used in an effort to calibrate or normalize the isotopic values. Analytical precision for $\delta^{13}\text{C}$ was $\pm 0.1\text{‰}$ with respect to the VPDB (Vienna PeeDee Belemnite) standard, and $\pm 0.2\text{‰}$ for $\delta^{15}\text{N}$ with respect to AIR (atmospheric nitrogen). Preservation of the dentin collagen was determined using collagen yields (%) and the C:N ratio per DeNiro (1985) and Ambrose (1990). Skeleton 115, a perinate, provided an unusual collagen yield of 100% from the vertebral centrum. Due to this anomalous collagen yield, skeleton 115 is fully reported in this paper but is not included in the statistical analyses.

3. Results

3.1. Isotope ratios of human bone collagen and dentin

Table 1 presents the results of the carbon and nitrogen isotope analysis, including C:N ratios, collagen yields, time period, demographics, and the root development stage of the tooth according to the London Atlas (Al Qahtani et al., 2010).

Overall $\delta^{13}\text{C}$ dentin values of Bögöz non-adults ($n = 20$) ranged from -19.6‰ to -12.6‰ with a mean of -18.4‰ and a standard deviation (stdev) of 1.7. The $\delta^{15}\text{N}$ dentin results ($n = 20$) ranged from 10.2‰ to 15.2‰ with a mean of 12.5‰ and standard deviation of 1.2. These dentin data points, along with three bone data points from skeletons 115, 158, and 247, are presented in Fig. 2. Most of the dentin results reveal diets within the range of what is broadly expected from non-adults; namely, higher nitrogen and carbon on average than a typical adult diet based on C₃ grains and terrestrial protein. However, several individuals fall outside of the typical C₃ range and suggest a diet

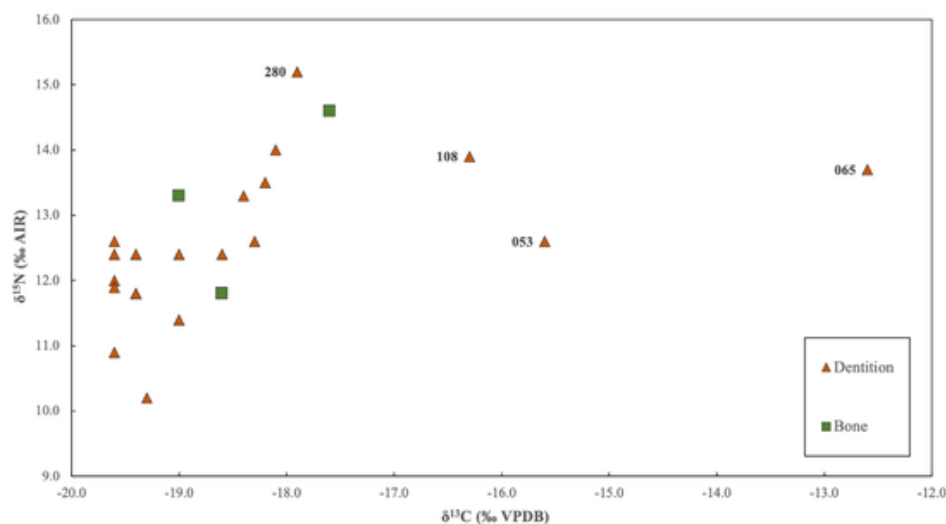


Fig. 2. Isotope results from Bögöz non-adults; outliers labeled.

more heavily supplemented by C₄ resources, specifically Skeletons 053, 065, and 108.

For the δ¹³C dentin collagen results, two individuals (065 and 053) were more than 2 stdev higher than the mean. Skeleton 053 exhibited a δ¹³C value of −15.6‰, and skeleton 065 had a δ¹³C value of −12.6‰, which is the highest carbon value in this tested population. These skeletons are associated with the 1700 and 1800 CE burials of the cemetery, and their high δ¹³C values may therefore be associated with the introduction of maize (*Zea mays*) to the region in the 18th century. Only one individual, skeleton 280, was 2 stdev higher than the δ¹⁵N dentin collagen mean. The tissue used for 280 was a left primary deciduous incisor with a development stage of R ½, meaning the sample likely reflects the diet at 0.4 to 0.9 years. The anomalous value may be associated with an enriched nitrogen value associated with the consumption of breastmilk. We considered as outliers those individuals whose isotope ratios were more than 2 stdev higher or lower than the mean. Because these three individuals only exhibit an anomalous value for one out of the two isotopes tested, these outliers will not be excluded from statistical analysis.

We collected data on bone values from the ribs and centra of 3 non-adults. While these cannot be directly compared with the data produced from the 20 sampled teeth, we nevertheless report the bones values here for the sake of completeness. From highest to lowest, the δ¹³C values are −17.6‰, −18.6‰, and −19.0‰, and the δ¹⁵N values are 14.6‰, 13.3‰, and 11.8‰. The highest values for both δ¹³C and δ¹⁵N come from a rib of skeleton 247, whose age at death was estimated to be 1.5 to 2.0 years. Skeletons 115 and 158 were neonates estimated to have been born between 36 and 38 weeks and 38 to 40 weeks, respectively. The samples from these two skeletons have δ¹³C and δ¹⁵N values that are similar to the overall dentin values from this study as well as the study conducted by [Peschel and colleagues \(2017\)](#), but upon closer inspection, are lower than the values that represent diet under the age of 4. While these samples cannot be compared statistically, they provide complementary data to the dentin results. For example, the δ¹³C and δ¹⁵N bone collagen values from the centra may represent the nutrients that were obtained *in utero*, as isotopic values of perinates are typically replications of their mothers' diets ([Beaumont et al., 2015](#)). Additionally, the infant rib sample exhibits a higher nitrogen value that is similar to the diets of individuals whose dentin collagen results represent the diets of infants under 4, which could indicate a breastfeeding signature ([Mays et al., 2002](#)). Further work is needed on bone collagen from non-adults in this cemetery.

No comparative faunal assemblage has yet been collected from Bögöz, due to the lack of animal remains in medieval and Early Modern

cemetery burials. Therefore, identifying specific dietary resources is not within our interpretive reach. However, from the overall dentin δ¹³C results, we are able to see that the majority of the non-adults at Bögöz were primarily eating C₃ based resources in both the weaning diet and post-weaned diet, likely in the form of wheat, aside from the few anomalous individuals. This finding supports the historic village laws from the region, where wheat was considered the most commonly cultivated cereal grain ([Molnár et al., 2015](#)). Additionally, the δ¹⁵N values of the tested population show that non-adults were eating a range of foods, which supports our hypothesis that there were dietary changes throughout the life course. The highest δ¹⁵N values in the tested population are from samples representing younger ages, and these values are likely attributable to breastfeeding practices, rather than to consumption of marine-based proteins, necessitating a closer look at nitrogen isotope variation. Based on the findings from the δ¹⁵N values, it appears that those in the tested population were consuming primarily terrestrial proteins after being weaned, supporting the historical evidence that referenced using mammalian milk from animals such as dairy cows, and consuming meat from wild game and farm animals, such as pigs ([Molnár et al., 2015](#)).

3.2. Nitrogen dietary variation during the life course

The δ¹⁵N values of dentin root samples and their respective development stages were further analyzed to determine patterns in dietary changes attributable to breastfeeding and weaning, key aspects of the non-adult life course ([Fig. 3](#)). Dentin from deciduous incisor roots (n = 2) had the highest δ¹⁵N values (15.2‰ and 13.7‰) and represents the youngest of the samples in terms of tooth root development, between 4.5 months and 2.5 years ([Al Qahtani et al., 2010](#)). Deciduous first molars, representing 7.5 months to 3.5 years (n = 4), had a δ¹⁵N average of 13.5‰ (stdev = 0.73). A lower δ¹⁵N (12.6‰) value was seen in the deciduous canine (n = 1), which represents 1.5 to 3.5 years ([Al Qahtani et al., 2010](#)). Finally, the deciduous second molars (n = 5) are lower still, with a δ¹⁵N average of 12.0‰ (stdev = 1.2). When combined, these δ¹⁵N dentin values (n = 12) represent the first three years of life ([Al Qahtani et al. 2010](#)) and range from 10.2‰ to 15.2‰. This age group has the highest mean (13.0‰) of all three tested age groupings, further indicating a trophic shift with consumption of breast milk.

Dentin from incisor roots that represent 5.5 to 11.5 years (n = 2) were similar in their δ¹⁵N values (12.6‰ and 12.4‰). The first molars, representing 3.5/4.5 to 9.5 years (n = 4) had a δ¹⁵N average of 11.7‰ with a standard deviation of 0.7. The δ¹⁵N values representing ages 4 to

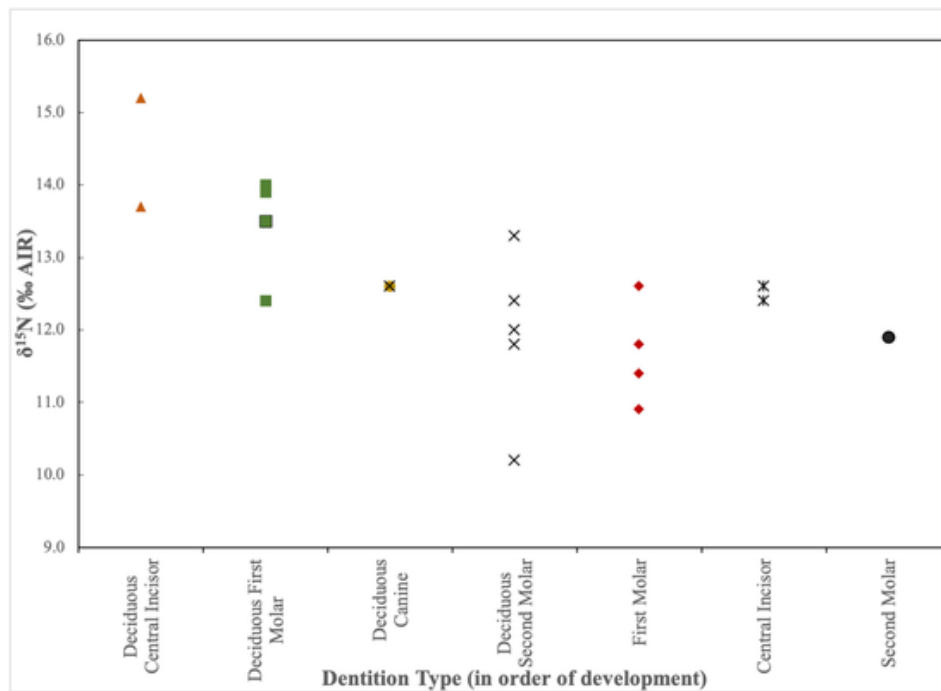


Fig. 3. Nitrogen values arranged by age of dentin formation.

9 ($n = 6$) ranged from 10.9‰ to 12.6‰ with a mean of 12.0‰ and standard deviation of 0.7. The two individuals (139 and 144) whose teeth represented the oldest developmental age tested (8.5 to 16.5) both exhibited a $\delta^{15}\text{N}$ value of 11.9‰ from the tested roots of second molars. Overall, there is an evident decrease in the $\delta^{15}\text{N}$ average with an increase in age, demonstrating a shift through the life course to lower trophic level foods.

Samples that represented the ages of individuals under the age of 10 ($n = 16$) were further analyzed using the Bayesian model WARN (Weaning Age Reconstruction with Nitrogen isotope analysis) following Tsutaya and Yoneda (2013). WARN 1.2 is an R package (R Core Team, 2000) that provides estimates of both the beginning and end of the weaning process (Chiniqué de Armas et al., 2017; Stantis et al., 2019; Tsutaya and Yoneda, 2013; Tsutaya et al., 2015). WARN takes into account the turnover rate of collagen, cross-sectional $\delta^{15}\text{N}$ data of non-adults aged less than ten years, as well as the $\delta^{15}\text{N}$ average of adult females from the same population (Stantis et al., 2019; Tsutaya and Yoneda, 2013). As summarized by Stantis et al. (2019), WARN calculates mean density estimates (MDE) and posterior probabilities of:

- t_1 : age at the initiation of weaning
- t_2 : age at the completion of weaning
- $E(\text{‰})$: the $\delta^{15}\text{N}$ -enrichment between mothers and infants
- $\delta^{15}\text{N}_{\text{wifood}}(\text{‰})$: nitrogen isotope value of weaning food.

In the WARN model applied here, $\delta^{15}\text{N}$ data from 16 non-adults were included using the adult female $\delta^{15}\text{N}$ mean (10.9‰) and standard deviation (0.85) reported in Peschel et al. (2017). Weaning parameters were estimated with WARN following Tsutaya and Yoneda (2013) and are presented in Table 2. Results from the WARN model are considered valid if the posterior probability for t_1 (i.e., age at the initiation of weaning) and t_2 (i.e., age at the end of weaning) MDEs are above 0.05 and the joint probability is above 0.0025 (Tsutaya and Yoneda, 2013; Stantis et al., 2019). In this study, posterior probabilities for t_1 and t_2 were 0.06 and 0.08, respectively, and the joint probability was 0.0113; therefore, the results of this analysis can be reliably interpreted.

For the Bögöz non-adults included in this study, t_1 and t_2 MDEs were 0.5 years and 4.2 years, respectively. The $\geq 95\%$ credible intervals (CIs) of the ages at the initiation (t_1) and completion (t_2) of weaning, the $\delta^{15}\text{N}$ -enrichment between mothers and infants (E), and the $\delta^{15}\text{N}$

Table 2

Mean density estimators (MDEs) for Bögöz non-adults generated with WARN.

Parameter	MDE		Range		Posterior Probability
	Estimator	Posterior Probability	Upper	Lower	
t_1	0.5	0.06	0.0	2.4	0.96
t_2	4.2	0.08	3.3	5.2	0.96
E (‰)	3.1	0.12	2.6	3.8	0.96
$\delta^{15}\text{N}_{\text{wifood}}$ (‰)	11.5	0.11	10.8	12.1	0.96

value of bone collagen produced from weaning foods ($\delta^{15}\text{N}_{\text{wifood}}$) were calculated and are presented as 0.0–2.4 years, 3.3–5.2 years, 2.6–3.8‰, and 10.8–12.1‰, respectively (see Table 2). The WARN package also produces a visual representation of measured and modeled dietary $\delta^{15}\text{N}$ values and modeled $\delta^{15}\text{N}$ values (Fig. 4). As demonstrated in Fig. 4, the measured nitrogen isotope values from Bögöz non-adults roughly conform to the model of a weaning process that starts just after birth and is completed by about age 4. The WARN results suggest that the onset of weaning for the tested non-adults at Bögöz occurred between 0 and 2.4 years, and that weaning was complete in this sample population between 3.3 and 5.2 years. Tsutaya (2017) presents a comprehensive meta-analysis of post-weaning diet in Holocene populations from around the world and provides an estimate of t_2 for 58 archaeological populations (see Tsutaya 2017, supporting information).

3.3. Carbon dietary variation

The $\delta^{13}\text{C}$ values of dentin root samples and their respective development stage of primary dentin were also analyzed. When observing the results overall, the values reflect a C_3 diet with the likely inclusion of a C_4 grain (possibly millet). Several outliers appear to have had a greater contribution of C_4 grains to their diet or consumed the meat or milk of animals foddered on a C_4 grain (i.e., millet).

Dentin from deciduous incisor roots ($n = 2$) had high $\delta^{13}\text{C}$ values when compared with the rest of the population, at -12.3‰ and -17.9‰ ; these represent the youngest of the samples in order of tooth

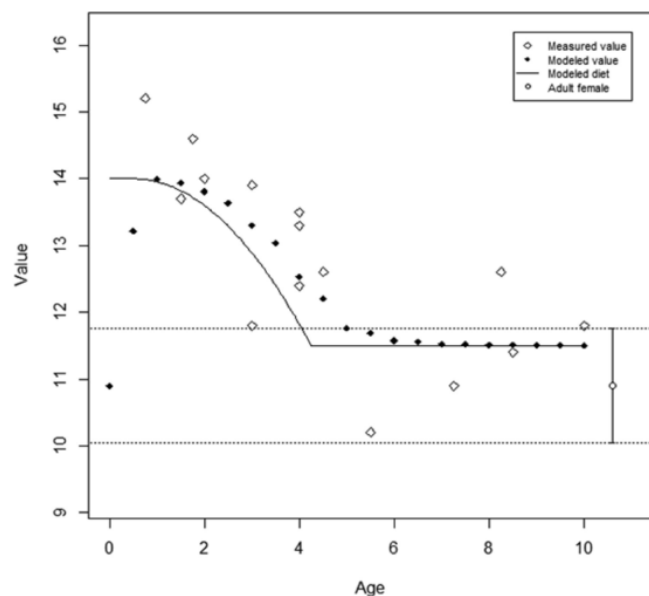


Fig. 4. Bögöz $\delta^{15}\text{N}$ bone values with measured and modeled $\delta^{15}\text{N}$ values and adult female mean ± 1 SD.

root development, between 4.5 months and 2.5 years (Al Qahtani et al., 2010). Deciduous first molars, representing 7.5 months to 3.5 years ($n = 4$), had a $\delta^{13}\text{C}$ average of -17.9‰ with a standard deviation of 1.1. This is likely due to the relatively high $\delta^{13}\text{C}$ of skeleton 108 (-16.3‰), whereas the other 3 tested individuals have lower values under -18.0‰ . The deciduous canine ($n = 1$), which represents 1.5 to 3.5 years (Al Qahtani et al., 2010), had a $\delta^{13}\text{C}$ value of -19.6‰ . This $\delta^{13}\text{C}$ value is considerably lower than the deciduous incisors and first molars, which represent diets associated with younger ages. The deciduous second molars ($n = 5$) had a $\delta^{13}\text{C}$ average of -19.1‰ , with a standard deviation of 0.5. Dentin from incisor roots that represent 5.5 to 11.5 years ($n = 2$) had vastly different $\delta^{13}\text{C}$ values (-15.6‰ and -19.4‰). It is possible that these disparities in value could be attributed to the time frames that each individual diet represents. Skeleton 053 ($\delta^{13}\text{C} -15.6\text{‰}$) lived around 1800 CE, around the time of introduction of maize, whereas skeleton 059 ($\delta^{13}\text{C} -19.4\text{‰}$) lived much earlier, most likely between 1300 and 1400 CE. The first molars, representing 3.5/4.5 to 9.5 years ($n = 4$) had a $\delta^{13}\text{C}$ average of -19.1‰ with a standard deviation of 0.6. Finally, the second molars of two individuals above age 9 (139 and 144) exhibited identical $\delta^{13}\text{C}$ values (-19.6‰).

Since there was an apparent shift in $\delta^{15}\text{N}$ values between ages 0 to 3 and 4 to 9, the $\delta^{13}\text{C}$ were also analyzed according to these shifts. The $\delta^{13}\text{C}$ values for those individuals 0–3 years ($n = 12$) ranged from -19.6‰ to -12.6‰ , with a mean of -18.1‰ and standard deviation of 1.9. Those with dentin development reflecting ages 4 to 9 ($n = 6$) had $\delta^{13}\text{C}$ values that ranged from -19.6‰ to -15.6‰ , with a mean of -18.6‰ and standard deviation of 1.5. The $\delta^{13}\text{C}$ average associated with ages 0 to 3 is higher than the values associated with ages between 4 and 18 years and includes the highest $\delta^{13}\text{C}$ value for the entire sample population (-12.6‰). These higher $\delta^{13}\text{C}$ values associated with the first three years of life may be attributed to breastfeeding, as infants that are exclusively breastfed will typically exhibit $\delta^{13}\text{C}$ values $+1\text{‰}$ higher than the average for adult females in the group (Fuller et al., 2006). However, the female $\delta^{13}\text{C}$ mean from the unpublished results of Peschel et al. (2017) is -18.5‰ , which is only 0.4‰ higher than the mean value for Bögöz non-adults between 0 and 3 years old. The introduction of C_4 crops into the weaning diet could also account for these higher values, however, if infants were consuming more dietary proteins in C_4 grains, either directly (as in porridge) or indirectly (through milk from C_4 foddered animals). Historically, there is evidence that C_4

grains such as millet were grown in the Eastern Carpathian Basin and Hungary at the time (Gyulai, 2010, 2014a, 2014b; Szűcs, 2002).

4. Discussion

Dietary trends of non-adults from the Bögöz cemetery population were found to be associated with the life course, particularly in regards to weaning. Based on previous isotope studies, we hypothesized that dentin collagen samples associated with the earlier periods of infancy would exhibit higher nitrogen values than samples that represent diets in older childhood (Britton et al., 2018; Burt, 2013; Fulminante, 2015; Molnár et al., 2015; Richards et al., 2002). In the non-adult Bögöz sample population, there was an observable decrease in average nitrogen values based on order of tooth root development and, by inference, a change in diet through the life course. In examining 20 non-adults, we also discovered that non-adult dietary proteins varied for individuals representing similar ages. Diet and social child-rearing practices may have varied due to the study's location in the Eastern Carpathian Basin, as it lies at a geographical, temporal, and cultural crossroads.

The higher nitrogen values for infants likely indicate a period where breast milk was the primary food being consumed. The decrease observed in Bögöz non-adult nitrogen values following infancy is likely related to the weaning process, and the medieval literature on childhood supports this, with a recommendation of total weaning to occur between the first and third year of life (Adamson, 2004; Orme, 2003). Based on the WARN analysis, the weaning process likely began around 6 months after birth for the Bögöz non-adults. However, unlike their contemporaries in more urban European environments (Britton et al., 2018), rural Székely children appear to have had a longer period of weaning that may not have ceased until the fourth year of life. This stands in stark contrast to other work in Medieval Europe that suggests urban children were completely weaned of breastmilk before the age of two (Britton et al., 2018). During the Early Modern period, artificial feeding became more popular in urban environments, and towards the end of the period, in the 19th century, women were working in higher numbers due to the Industrial Revolution (Papastavrou, 2015). It is possible that in rural Transylvania, these overarching trends in the United Kingdom and Central Europe were not being implemented to the same degree and that mothers were able to breastfeed for longer periods because of the difference in the social requirements of women at that time as well as a delay in artificial feeding trends.

One individual stands out as anomalous within the overall pattern seen in the sampled population's $\delta^{15}\text{N}$ results. Skeleton 281 was between 5 and 6 years old at death; their deciduous second molar was tested, providing a window into their diet at the developmental age range of 1.5 to 3.5 years. Their measured $\delta^{15}\text{N}$ value of 10.8‰ is nearly 2‰ lower than the overall non-adult mean of 12.5‰ . It is therefore likely that skeleton 281 was weaned earlier than the rest of the sampled non-adult population and it is possible that the early cessation of weaning could have ultimately led to the early death of the individual. Research has found that there is a link between infant stress, mortality, and breastfeeding or weaning practices (McDade and Worthman, 1998; Stuart-Macadam and Dettwyler, 2017). It is also possible that the breast milk the individual was consuming could have come from an individual with a markedly different diet from the rest of the population, consuming considerably less animal protein. Therefore, the $\delta^{15}\text{N}$ may have been considerably lower than the female average, which would have resulted in the low $\delta^{15}\text{N}$ value of skeleton 281.

There is a 7‰ range in carbon isotope values for teeth that represent the first three years of life, meaning the overall protein component of diet associated with early life for the tested individuals was markedly varied. This dietary breadth for infants provides evidence of a diet that was not homogeneous nature. It is possible that this dietary breadth could be attributed to the large time frame that the samples represent or to the result of mixed cultural practices associated with in-

fant rearing as it relates to what foods the caregiver was providing for these infants. [Peschel and colleagues \(2017\)](#) noted that the adults in the population were consuming less protein from animals during 1100–1200 CE than in later time periods, a time rife with political turmoil and cultural change associated with invading countries and colonization. It is possible that these external factors may have impacted the resources that were provided to the younger members of the village as well, however only 10% of those tested likely lived during this period and 30% lived in the subsequent period (1200–1300 CE).

Medieval literature from Central and Western Europe suggests that the primary weaning foods were paps and panadas; pap consisted of watered-down flour or bread, and panada was composed of cereal grains or flour in a broth, which was generally meat-based, and flavored with milk or butter ([Adamson, 2004](#); [Lewis, 2007](#); [Obladen, 2014](#)). The grain-based resources in these paps and panadas could have varied based on what resources were available at the time. Though the village laws cite wheat, barley, and oats as the three main crops in Székelyföld villages ([Molnár et al., 2015](#)), all C₃ based grains, millet husks and seeds have been found at numerous archaeological sites in the Eastern Carpathian Basin and Hungary, of which Bögöz was a part of ([Gyulai, 2010, 2014a, 2014b](#); [Szűcs, 2002](#)). [Gyulai \(2014a:43\)](#) cites broomcorn millet (*Panicum miliaceum*) as a “favorite gruel plant” in the medieval period in Hungary and it is known that millet gruel was commonly consumed in Hungary until the introduction and adoption of maize in 1700–1800 CE ([Gyulai 2014a](#)) and it is therefore possible this resource was consumed to varying degrees as gruel for weaning infants within Bögöz if commonly used in gruels throughout the Hungarian Kingdom.

Since weaning is typically a prolonged period of slow introduction of soft foods, the variation evident in the Bögöz non-adult weaning diet could also be the result of dietary practices of breastfeeding mothers themselves. Poultry with dried or fresh fruits such as figs, prunes, and apple with honey were the primary foods pregnant women were supposed to consume in 18th century Transylvania ([Fehér, 2011](#)). These regulations follow the general medieval European diet for expectant mothers, aside from the inclusion of sweet wine ([Weiss-Amer, 1993](#)). In 18th century Transylvania, wine was strictly prohibited for pregnant women, as was beef and milk ([Fehér, 2011](#)). The changes in breastfeeding mothers' diets could have changed the composition of their breast milk depending on how strictly mothers followed the dietary regimen and depending on whether this regimen was implemented in earlier centuries, which could have contributed to the variability of the isotope values in their unweaned infants.

Skeletons 107 and 108 also provide us a unique perspective on the varied weaning diet at Bögöz. These two individuals were between 2 and 4 years old at death and were both buried in the same grave dating to the 17th century. Although their nitrogen values from deciduous first molars are similar (14.0‰ and 13.9‰, respectively), their carbon values are markedly different (−18.1‰ and −16.3‰, respectively). It appears that one child was fed primarily C₃ resources, and the other was likely fed more C₄ based resources. As discussed above, millet was available in Hungary and the Eastern Carpathian Basin at the time, and it was also a common animal fodder in medieval Europe. Therefore, the higher carbon signature in skeleton 108's infancy could reflect greater consumption of products such as milk or butter from millet-foddered animals ([Tafari et al., 2009](#)) or the inclusion of millet in their weaning food. Additional isotope research along these lines has the potential to increase this small sample size and more accurately detect the cultural weaning practice at Bögöz.

The teeth that represent ages 3 and up demonstrate consumption of a diet based on locally sourced plants and animals. The majority of those tested were consuming both C₃ and C₄ resources and terrestrial proteins. It is likely that children consumed largely terrestrial resources such as pigs, sheep, cattle, and their products, based on village laws and other historical sources ([Adamson, 2004](#); [Molnár et al., 2015](#)). [Peschel](#)

[and colleagues \(2017\)](#) suggest, based on their isotope analysis of the adult sample from Bögöz, that the bulk of their dietary protein likely came from pork. Rather than a high consumption of omnivorous proteins, it is possible that some of the higher nitrogen and carbon values come from freshwater proteins, as the village laws cite freshwater fish. Although the Târnava Mare river is nearby, the activity of fishing was only permitted to nobles in the villages and was heavily regulated ([Molnár et al., 2015](#)) and it is therefore unlikely that this protein contributed greatly to the overall diet. The isotopic findings for the post-weaned childhood diet are bolstered by frequencies of dental caries in the non-adult dentition at Bögöz and by historical suggestions of grain-heavy diets among rural villagers ([Dyer, 1998](#)). Those who died in later time periods, however, present isotope values that raise intriguing new questions about changes in alimentary resource use through time. Although diet was not significantly different in terms of carbon and nitrogen averages in the first 600 years of cemetery use, the last time period of 1700–1800 CE may represent a key turning point in resource use: the incorporation of maize as a crop in the Székelyföld. Skeleton 053, for example, has a high carbon value (−15.6‰), having likely eaten primarily C₄ resources. Dating to 1800 CE, this individual may have been consuming maize. Primarily used as animal fodder following its introduction to Europe ([Larsen, 2015](#)), it appears that maize was consumed by humans and potentially by animals in the Székelyföld. Village laws suggest that maize, along with the potato, replaced wheat, oats, and barley as staple crops towards the Early Modern period in this area ([Molnár et al., 2015](#)). Skeleton 065 had the carbon value, at −12.6‰, however from the $\delta^{15}\text{N}$ findings, this individual was likely breastfeeding or in the early stages of weaning at a time when maize was introduced into the diets of Transylvanians, which would explain the extremely elevated carbon value when compared with the rest of the sampled population. Finally, two (139 and 144) second permanent molars were tested, which represent the oldest age range tested in this population. Their values were identical to one another in both their nitrogen and carbon results (11.9‰ and −19.6‰). While it is unclear why these two individuals had identical values, they were consuming a diet of mostly C₃ resources and terrestrial proteins. Though these individuals are nearing that of a marine based diet, we know that fishing was heavily regulated, and is unlikely that these individuals were consuming vast amounts of fish in their diet. The higher nitrogen values are likely attributed to the primary component of their animal protein coming from pork, which tends to exhibit higher $\delta^{15}\text{N}$ than herbivores ([Gugora et al., 2018](#)).

In sum, a change in diet during the life course for children at Bögöz is evident from palaeodietary isotope analysis, particularly in between infancy and childhood, when children were weaned from breast milk onto progressively more adult-like foods; these adult foods likely consisted of terrestrial proteins from herbivorous and omnivorous animals and both C₃ and C₄ resources, like wheat, millet, and for the later time periods, maize. The results of the WARN analysis suggest that among Székely children from this village, weaning was likely initiated around six months after birth and was completed before children reached their fifth birthday. While weaning results generated in this study broadly correspond with trends described elsewhere in Europe ([Fulminante 2015](#)), additional research evaluating differences in the timing of weaning between rural and urban European environments across time is warranted. For example, [Haydock and colleagues \(2013\)](#) examined changes in the timing and duration of breastfeeding over a 2000-year period in the UK and observed that the weaning process continued to shorten as time progressed and industrialization increased. [Britton et al. \(2018\)](#) confirmed this temporal shift in medieval and post-medieval Aberdeen. As Aberdeen became more industrial, weaning initiated sooner and was completed before children reached the age of two ([Britton et al., 2018](#)). These examples from more urban bioarchaeological contexts in the UK stand in stark contrast to the results of this study at rural Bögöz, which suggest weaning may have been prolonged by

two years. Additional research is warranted in Transylvania, and among Székely communities in particular, due to relatively longer periods of non-industrialization (Molnár et al., 2015). On-going isotopic work examining non-adults from other Székely villages may provide clarity.

Although we were able to produce insightful discoveries into the diets of non-adults from a village community in the Eastern Carpathian Basin, it is important to note that this study has its limitations. Due to the relatively small sample size and representation of several centuries, this serves as a preliminary case study. Additionally, this study utilized a cross sectional approach, rather than a longitudinal approach, by testing the roots of teeth that represent different ages of development. We are therefore only able to observe broad dietary trends from a small sample, rather than a change in diet over the life course of an individual. It is also important to note that many of the individuals used in this study did not make it to adulthood, and therefore these data may be biased and may not fairly represent weaning practices and resource access for children at Bögöz. Additional research could create a more holistic understanding of non-adult diet from birth to adolescence, specifically by using serial micro-sampling techniques to trace individual dietary patterns. This method may elucidate weaning trends and help explain the large variability observed in the weaning age and post-weaned diet in medieval Transylvania.

5. Conclusion

The overall diet of 20 non-adults who were buried in the reformed church cemetery in Bögöz, Transylvania, between 1100 and 1800 CE, consisted of C₃ and C₄ based resources and terrestrial protein sources. Although the isotopic results were overall similar for all tested non-adults, closer examination of the data shows that differences in dietary resources existed for the different age brackets, specifically those of infants, children, and adolescents, suggesting alimentary resource variation through the life course. Infants were likely consuming breast milk and were weaned using C₃ and C₄ grains and animal proteins in the form of milk or butter, and children and adolescents were likely eating foods similar to the ones the adults in the population consumed. The introduction of maize in the 18th-19th century is reflected in the diets of individuals buried during this time period. Further exploration into the weaning diet, dietary change through the life course, and the introduction of maize to rural Eastern Europe using a more robust sample population is warranted.

Uncited references

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CRedit authorship contribution statement

Maddeline R. Voas: Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing, Visualization. **Kristina Killgrove:** Conceptualization, Methodology, Investigation, Writing - review & editing, Supervision, Visualization. **Robert H. Tykot:** Resources, Writing - review & editing, Investigation, Supervision, Visualization, Data curation. **Zsolt Nyaradi:** Resources, Methodology, Data curation.

Andre Gonciar: Resources. **Jonathan D. Bethard:** Conceptualization, Methodology, Supervision, Writing - review & editing, Visualization, Data curation, Formal analysis.

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