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Neolithic Lifeways at the Microlevel: Isobiographies From Italy

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ABSTRACT

Characterization of prehistoric lifeways tends to work at the level of generalization, but can we investigate microvariation? For example, it is common to discuss the “Neolithic diet”, but how much did what people ate vary, not only between individuals but from year to year or from place to place? Similarly, discussions of mobility tend to focus either on large-scale population movements or on lifelong changes in residence, implying that people remained statically in their villages under other circumstances, but how much did people normally move around the landscape? The “isobiography” approach we apply here combines fine-grained incremental sampling of multiple isotopes to investigate these questions. Here, we explore the life histories of five Neolithic individuals from Passo di Corvo (Foggia) and Titolo (Bari) in Puglia, southeastern Italy, by analyzing the stable carbon, nitrogen, and sulfur isotopic signals from bone elements and dentine increments. Our findings unveil nuanced individual narratives. Variations in breastfeeding and weaning practices suggest flexible cultural norms; aquatic resources may have been introduced during weaning and their consumption continued during childhood in some individuals. Broadly, our findings reveal adaptations throughout the lifespans studied, potentially reflecting dietary shifts or physiological responses to climatic, environmental, or nutritional challenges. Additionally, our data indicate connections beyond local contexts: Some individuals were mobile over short ranges (Passo di Corvo), whereas others displayed connections to more distant inland locations (Titolo). Our study underscores the complexity of Neolithic lifeways, demonstrating variations not only between individuals but also within the lifespan of a single individual.

1 | Introduction

There is an old statistical joke about a person lying on the kitchen floor with their head in the refrigerator and their feet in the oven. When asked how they find the temperature, they answer "fine, on average." Averages and aggregate data mask variability, but sometimes, variability is important. Taking analysis to a more granular level gives a clearer, immediate sense of how people actually lived and how much their lives varied. Microvariation may also be important analytically. Averages can mask important rhythms such as seasonal variability or different periods of a person's life cycle. They can also mask change, for instance, how subsistence changes during a bad year for crops, or how small settlements may have demographic growth or collapse, and how people cope actively and creatively with such circumstances.

This paper explores these issues for Neolithic southeastern Italy. This region is well studied, particularly in areas such as diet and mobility (Arena et al. 2020; Lelli et al. 2012; Tafuri et al. 2023; Tafuri et al. 2014, 2016a). However, as their diet gravitated around a well-documented norm of a mostly terrestrial, plant-rich diet based on domesticates, how much did they vary their foods throughout their life or circumstantially? In terms of mobility, discussions of Neolithic movement have tended to focus either on the macroscale of population movements associated with the beginning of farming, or on individuals moving permanently from one place to another, perhaps as part of a marital strategy (Borić and Price 2013; Knipper et al. 2017). Theoretical models for Italian Neolithic societies postulate a continual low-level flow of people between nearby sites for social, economic, and demographic reasons (Robb 2007; Tafuri et al., 2016a, 2016b), but documenting micromobility has not hitherto been possible methodologically.

The isotopic signal of bone represents an average value of more than 10 years of an adult's life (Hedges et al. 2007), flattening an individual's residence or dietary patterns. Stable isotope analysis of dentine increments has been developed as a way to overcome these limitations (e.g., Beaumont et al. 2013). Contrary to bone, primary dentine does not remodel; therefore, the sampling of portions of dentine corresponds to isotopic changes from the time of formation of the dentine until its completion. Numerous studies have employed this approach to examine the early years of life, highlighting breastfeeding and weaning practices in ancient societies (e.g., Beaumont et al. 2013; Scharlotta et al. 2018; Goude et al. 2020). By combining the signals from dentine increments across multiple teeth, it is possible to outline a timeline from early life and into adolescence or even young adulthood within individuals. Supplementing these with the bone signal of later life, the aggregate results produce an "isobiography" (Eerkens and Bartelink 2023). Here, we apply the isobiography approach using stable carbon, nitrogen, and sulfur isotope analysis to define the dietary and possible mobility histories of five Neolithic individuals from Titolo (Palese, Bari) and Passo di Corvo (Foggia) (Radina et al. 2020; Tinè 1983).

1.1 | The Sites, the People, the Landscapes

Neolithic lifeways emerged in southeastern Italy just before the 6th millennium BCE. Small groups of farmers established themselves along coastal plains, lagoons and rivers, including at Passo di Corvo and Titolo (Figure 1) (Caldara et al. 2011). In these regions, the "Neolithic package" consisted of domesticated crops and animals, structured villages, funerary and domestic rituals, and the use and exchange of materials (Robb 2007). Recent isotopic studies confirm that their diet was mainly composed of C_3 cereals such as wheat and barley, legumes, and animal products, potentially supplemented by low quantities of aquatic resources in some coastal areas (Lelli et al. 2012; Tafuri et al. 2014, 2023). These communities maintained contact with each other with trade networks and shared funerary practices, particularly during the 5th millennium BCE (Radina et al. 2020; Thompson et al. 2024). Detailed information on Passo di Corvo and Titolo are reported in the Supporting Information.

2 | Materials and Methods

2.1 | Materials

Bone and tooth samples were available from one adult male (T6) and two probable males (T2 and T3) from Titolo and one adult male (T5) and one adult whose undeterminable osteological sex (T11) from Passo di Corvo. One tooth from T10bis from Passo di Corvo was also preliminarily analyzed through incremental dentine. Because the results are not fully comparable with the other individuals reported in this paper due to the application of different protocols, these are reported in the Supporting Information.

Ethical approval was given by the University of Cambridge. Research followed internal project ethical guidelines for invasive analysis, with permission from the *Soprintendenza*. Bulk analysis of further human and faunal bones from both sites and faunal remains from the nearby, contemporary site of Masseria Candelaro (Foggia) provided comparative and baseline data (Table 1 and Supporting Information).

2.2 | Methods

Diet and mobility were investigated by analyzing $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ (‰) from human bone and dentine samples and local fauna. Osteological analysis was performed on Titolo (see the Supporting Information), whereas the human remains from Passo di Corvo were previously recorded by Mariotti et al. (2020). Standard protocols were followed for collagen extraction (Longin 1971; Tuross 2012), and incremental analysis followed Beaumont et al. (2013). Collagen samples were run at SUERC, East Kilbride (United Kingdom), and the analytical precision was determined to be ±0.15‰, ±0.2‰, and ±0.4‰ for $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ (‰), respectively. Collagen quality was assessed following Ambrose (1990) and Nehlich and Richards (2009). Age alignment was conducted as per Czermak et al. (2020) and AlQahtani et al. (2010). Radiocarbon dating was also performed at SUERC on collagen from three individuals from Titolo (Table S1 and Figure S1). Zooarchaeology by Mass Spectrometry (ZooMS) was used to provide taxonomic identification of the fauna from Titolo (Buckley et al. 2009). Full methodological details and justification are provided in the Supporting Information.

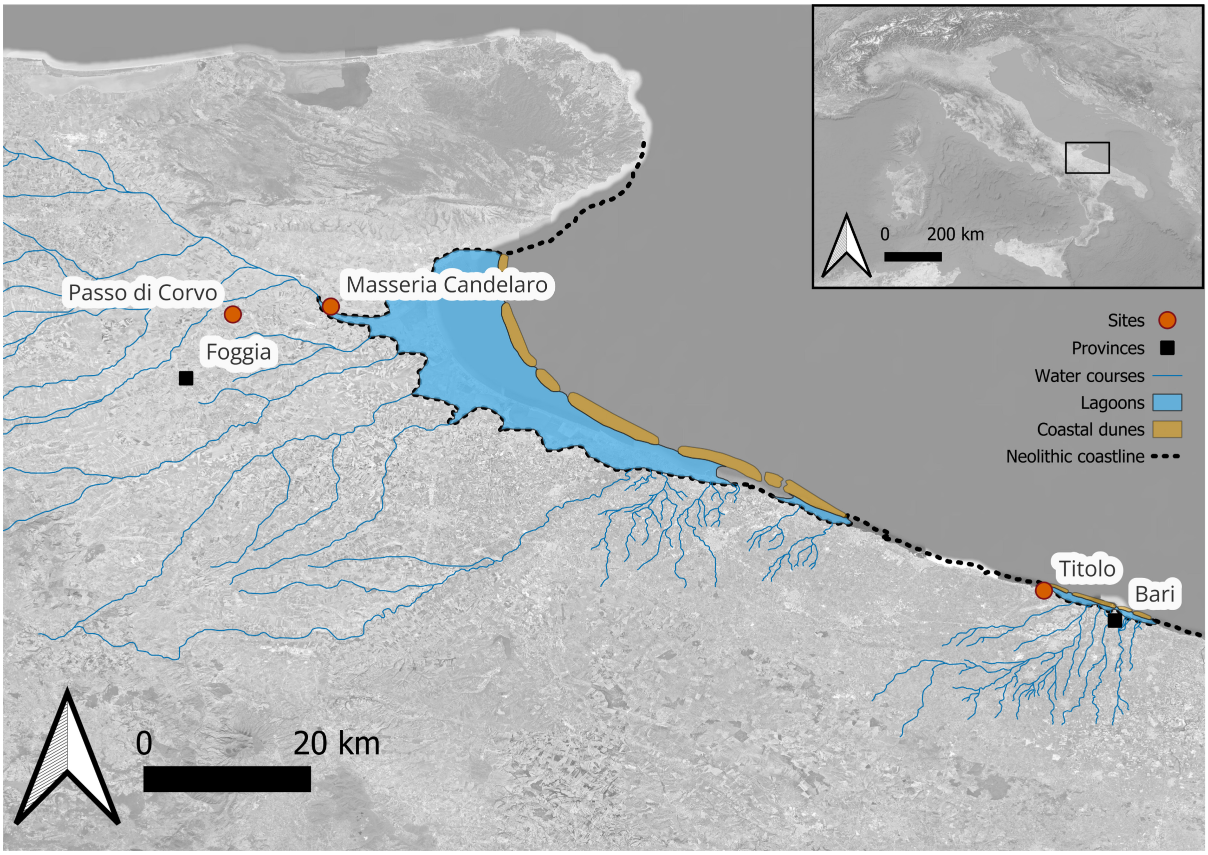

FIGURE 1 | Location of Titolo (BA) and Passo di Corvo (FG) from southeastern Italy with indication of Neolithic geomorphological features modified after Caldara et al. (2011). The location of Masseria Candelaro (FG) is also reported. QGIS versus 3.34.2, base map ESRI Satellite; by SP. [Colour figure can be viewed at wileyonlinelibrary.com]

3 | Results

3.1 | General Characterization of Background Patterns Using Bulk Isotopes

Bulk isotope results are summarized in Table 2.

3.1.1 | Titolo

At Titolo, faunal samples show $\delta^{13}C$ mean values of -20.6 ± 0.7‰ ($\Delta^{13}C_{max\text{-}min} = 2.4$) and $\delta^{15}N$ mean values of 6.1 ± 0.7‰ ($\Delta^{15}N_{max\text{-}min} = 2.5$), which are in line with a diet largely composed of C_3 plants, typical of the area (Lelli et al. 2012; Tafuri et al. 2014, 2023; Arena et al. 2020). The $\delta^{34}S$ mean values—if we exclude the outlier sample PT6_1 (then of 12.6 ± 0.9‰; $\Delta^{34}S_{max\text{-}min} = 2.7$)—are similar to those observed for one sheep from Ripa Tetta (a site 45 km inland) (Lelli et al. 2012) and for animals from areas located on (or up to 20–30 km away from) the Tyrrhenian coast (Varalli et al. 2016).

The human bones $\delta^{13}C$ mean values are -19.6 ± 0.4‰ ($\Delta^{13}C_{max\text{-}min} = 1.3$), and $\delta^{15}N$ mean values are 8 ± 0.7‰ ($\Delta^{15}N_{max\text{-}min} = 2.7$), typical of a diet mainly composed of C_3 resources. In contrast, $\delta^{34}S$ mean values of 6.9 ± 3.7‰ ($\Delta^{34}S_{max\text{-}min} = 11.3$) differ from those of the site's fauna. The relatively high faunal $\delta^{34}S$ values—which are notably higher than in humans—may reflect a coastal location partly influenced by the sea-spray effect (Zazzo et al. 2011), such as Titolo itself. This would suggest that many of the humans were not local to their place of burial and likely originated from more inland locations.

As for the human dentine samples, the $\delta^{13}C$ mean ($n = 50$) values of -19.8 ± 0.6‰ ($\Delta^{13}C_{max\text{-}min} = 2.9$) and $\delta^{15}N$ mean ($n = 50$) values of 8.2 ± 0.7‰ ($\Delta^{15}N_{max\text{-}min} = 4.5$) resemble those obtained from the human bones, suggesting that these values are quite homogeneous throughout the "portions" of life of T2, T3, and T6, and therefore their diet. The wide $\Delta^{15}N_{max\text{-}min}$ range reflects the elevated $\delta^{15}N$ in T2's early crown sections, likely due to breastfeeding. On the other hand, the $\delta^{34}S$ mean ($n = 40$) values are 9.3 ± 4.4‰ and vary considerably ($\Delta^{34}S_{max\text{-}min} = 12.5$), suggesting differences across the life courses of these three individuals.

3.1.2 | Passo di Corvo

The $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ values of the few faunal samples from Passo di Corvo fall within the distribution of those from Masseria Candelaro; they can therefore be discussed as a single group. These ($n = 14$) exhibit $\delta^{13}C$ mean values of -20 ± 1‰ ($\Delta^{13}C_{max\text{-}min} = 3.4$) and $\delta^{15}N$ mean values of 6.8 ± 1.3‰ ($\Delta^{15}N_{max\text{-}min} = 4.5$). $\delta^{34}S$ mean values are 9 ± 1.9‰ ($\Delta^{34}S_{max\text{-}min} = 5.8$), slightly lower than at Titolo, reflecting different coastal proximity (from modern coast: Masseria Candelaro ~12 km; Passo di Corvo ~24 km; and Titolo < 1 km).

TABLE 1 | Human and animal remains from Titolo, Passo di Corvo, and Masseria Candelaro selected for stable carbon, nitrogen, and sulfur isotope analysis. Tooth numbers follow the Fédération Dentaire Internationale notation (Fédération Dentaire Internationale 1971).

Site	Archaeo ID	Species	Sex	Age	14C determination ± standard deviation (BP)	14C calibrated date range with probability range (cal BC, 95.4%)	14C lab ID	Bone element	Tooth
Titolo Palese (BA)	T1	*Homo sapiens*	ND	Adult				L femur	
Titolo Palese (BA)	T2	*H. sapiens*	?M	25–35	6541 ± 50	5617–5380 cal BC	LTL-15552A	L femur	36, 37, 38
Titolo Palese (BA)	T3	*H. sapiens*	?M	35–45	6452 ± 29	5479–5363	SUERC-106332	Rib	27
Titolo Palese (BA)	T4	*H. sapiens*	ND	12–18				R femur	
Titolo Palese (BA)	T5	*H. sapiens*	?M	Adult				Rib	
Titolo Palese (BA)	T6	*H. sapiens*	M	35–45	6230 ± 50	5311–5045	LTL-14541A[a]	R fibula	23
Titolo Palese (BA)	T7	*H. sapiens*	ND	4.5–6.5	6381 ± 24	5471–5229	SUERC-106949	Rib	
Titolo Palese (BA)	T8	*H. sapiens*	?F	35–45	Failed		GU61653	L femur	
Titolo Palese (BA)	T9	*H. sapiens*	F	35–45	6815 ± 45	5786–5627	LTL-19755A[a]	Rib	
Titolo Palese (BA)	T10A	*H. sapiens*	?F	45–60				L phalanx	
Titolo Palese (BA)	T10B	*H. sapiens*	ND	8 ± 2				Rib	
Titolo Palese (BA)	PT10_301_2	*Ovis vel Capra* (ZooMS)						Ulna	
Titolo Palese (BA)	PT10_301_1	*Ovis vel Capra*						Radius	

(Continues)

TABLE 1 | (Continued)

Site	Archaeo ID	Species	Sex	Age	14C determination ± standard deviation (BP)	14C calibrated date range with probability range (cal BC, 95.4%)	14C lab ID	Bone element	Tooth
Titolo Palese (BA)	PT10B_1	*Ovis vel Capra*						Calcaneus	
Titolo Palese (BA)	PT10B_300/301_1	*Sus domesticus* (ZooMS)						Maxilla	
Titolo Palese (BA)	PT2_2	Medium size mammal						Rib	
Titolo Palese (BA)	PT3_1	*Ovis vel Capra*						Phalanx	
Titolo Palese (BA)	PT3_2	*Ovis aries* (ZooMS)						Rib	
Titolo Palese (BA)	PT6_1	*Bos taurus* (ZooMS)						Fragment	
Titolo Palese (BA)	PT7_186_1	*O. aries* (ZooMS)						Mandible	
Titolo Palese (BA)	PT7_190_1	*O. aries* (ZooMS)						Vertebra	
Titolo Palese (BA)	PT9_1	*B. taurus* (ZooMS)						Phalanx	
Passo di Corvo (FG)	T5	*H. sapiens*	M[b]	18–25				R humerus	26
Passo di Corvo (FG)	T10bis	*H. sapiens*	ND[b]	Adult[b]					26
Passo di Corvo (FG)	T11	*H. sapiens*	ND[b]	18–25				Cranium	16, 28
Passo di Corvo (FG)	PC BOS1	*B. taurus*						Radius	
Passo di Corvo (FG)	PC BOS2	*B. taurus*						Radius	

(Continues)

TABLE 1 | (Continued)

Site	Archaeo ID	Species	Sex	Age	14C determination ± standard deviation (BP)	14C calibrated date range with probability range (cal BC, 95.4%)	14C lab ID	Bone element	Tooth
Passo di Corvo (FG)	PC OVIS3	*Ovis vel Capra*						Radius	
Passo di Corvo (FG)	PC OVIS5	*Ovis vel Capra*						Metatarsus	
Masseria Candelaro (FG)	BOS 13	*B. taurus*						Phalanx	
Masseria Candelaro (FG)	BOS 14	*B. taurus*						Pelvis	
Masseria Candelaro (FG)	BOS 15	*B. taurus*						Phalanx	
Masseria Candelaro (FG)	BOS 16	*B. taurus*						Radius	
Masseria Candelaro (FG)	CAPR. 2	*Capreolus capreolus*						Mandible	
Masseria Candelaro (FG)	OVC 3	*Ovis vel Capra*						Metatarsus	
Masseria Candelaro (FG)	OVIS 4	*Ovis vel Capra*						Tibia	
Masseria Candelaro (FG)	OVC 5	*Ovis vel Capra*						Scapula	
Masseria Candelaro (FG)	OVC 6	*Ovis vel Capra*						Tibia	
Masseria Candelaro (FG)	SUS 7	*S. domesticus*						Tibia	
Masseria Candelaro (FG)	SUS 8	*S. domesticus*						Pelvis	
Masseria Candelaro (FG)	SUS 9	*S. domesticus*						Fibula	

(Continues)

TABLE 1 | (Continued)

Site	Archaeo ID	Species	Sex	Age	14C determination ± standard deviation (BP)	14C calibrated date range with probability range (cal BC, 95.4%)	14C lab ID	Bone element	Tooth
Masseria Candelaro (FG)	SUS 10	*S. domesticus*						Scapula	
Masseria Candelaro (FG)	SUS 11	*S. domesticus*						Pelvis	
Masseria Candelaro (FG)	SUS 12	*S. domesticus*						Pelvis	

[a]Radina et al. (2020).
[b]Mariotti et al. (2020).

TABLE 2 | Descriptive statistics for human and faunal bone and human incremental dentine collagen isotopic compositions of samples from Titolo (BA) and Passo di Corvo (FG). Animals from Passo di Corvo include samples from the nearby site of Masseria Candelaro.

	Titolo																	
	$\delta^{13}C$ (‰)						$\delta^{15}N$ (‰)						$\delta^{34}S$ (‰)					
	n	Mean	1 SD	Median	Min	Max	*n*	Mean	1 SD	Median	Min	Max	*n*	Mean	1 SD	Median	Min	Max
Humans	11	−19.6	0.4	−19.5	−20.4	−19.1	11	8.0	0.7	8.0	6.3	9.0	11	6.9	3.7	7.0	2.4	13.7
Animals	11	−20.6	0.7	−20.7	−21.5	−19.1	11	6.1	0.7	6.1	5.0	7.5	11	12.1	1.9	12.2	7.0	14.1
Dentine increments	50	−19.8	0.6	−19.9	−21.6	−18.7	50	8.2	0.7	8.1	7.3	11.8	40	9.3	4.4	11.3	1.8	14.3
	Passo di Corvo																	
	$\delta^{13}C$ (‰)						$\delta^{15}N$ (‰)						$\delta^{34}S$ (‰)					
	n	Mean	1 SD	Median	Min	Max	*n*	Mean	1 SD	Median	Min	Max	*n*	Mean	1 SD	Median	Min	Max
Humans	17	−19.2	0.3	−19.1	−20.0	−18.8	17	9.0	0.7	8.7	7.9	10.4						
Animals	14	−20.0	1.0	−20.3	−21.1	−17.7	14	6.8	1.3	6.5	5.2	9.8	14	9.0	1.9	9.3	5.5	11.3
Dentine increments	39	−19.5	0.7	−19.6	−21.4	−18.1	39	9.7	1.3	9.4	7.9	13.8	34	12.0	1.5	12.3	8.4	15.0

The wide range distribution could suggest variability in the animals' rearing locations, as well as the region's abundant wetlands mixing freshwater and marine influences (e.g., Guiry et al. 2021).

Human bulk isotope values were based on previously published carbon and nitrogen data ($n = 15$) from Passo di Corvo (Tafuri et al. 2023). Bones of T5 and T11 were resampled to also provide sulfur isotope signatures; however, T5 was excluded due to %S values exceeding collagen quality thresholds, as defined in the methodological criteria. T5 has $\delta^{13}C = -20‰$ and $\delta^{15}N = 9.9‰$, whereas T11 (H.1) exhibits $\delta^{13}C = -19.9‰$, $\delta^{15}N = 9.1‰$, suggesting that these two individuals had a terrestrial diet based on the consumption of C_3 resources, in line with the rest of the population (Tafuri et al. 2023). T11 has $\delta^{34}S = 10.5‰$, like those observed in the local fauna: They came from the same region and had a predominantly terrestrial diet. The same conclusion was also reached using strontium analysis (Tafuri et al. 2016a).

Dentine increments from Passo di Corvo show $\delta^{13}C$ mean ($n = 39$) values of $-19.5 \pm 0.7‰$ ($\Delta^{13}C_{max\text{-}min} = 3.3$), $\delta^{15}N$ mean ($n = 39$) values of $9.7 \pm 1.3‰$ ($\Delta^{15}N_{max\text{-}min} = 5.9$), and $\delta^{34}S$ mean ($n = 34$) values of $12.0 \pm 1.5‰$ ($\Delta^{34}S_{max\text{-}min} = 6.6$). The low variation observed in the stable carbon isotope values suggests a similar diet of the C_3 type throughout the lives of individuals T5 and T11. Higher $\delta^{15}N$ (‰) values are observed in the earlier phases of their lives, probably caused by breastfeeding. Stable sulfur isotope values are variable, suggesting some degree of mobility and/or fluctuating consumption of aquatic resources.

The classic bulk approach using stable carbon, nitrogen, and sulfur isotopes suggests a standard Neolithic diet, composed of terrestrial C_3 resources, mostly plants, at both sites. The stable sulfur isotope values, however, may imply a certain range of mobility from coast to inland locations (and *vice versa*), consumption of aquatic resources, or physiological factors.

3.2 | Isobiographies

In this section, we compile isobiographies of the five individuals. Each is accompanied by the stable isotopic signatures of humans and fauna from the site. Error bars of dentine increments reported in the graphs (e.g., Figure 2) only indicate the assumed period of growth of each section, not uncertainties around the estimated time of growth, which is known to be much larger (Tsutaya 2020). We have applied the mathematical method proposed by Tsutaya (2020) to observe the degree of variability of our data and reported the results in the Supporting Information (Figures S2–S18).

3.2.1 | T2 From Titolo

The individual from Burial 2 is a probable male, estimated to be 25–35 years old at death and radiocarbon dated to 5617–5380 cal BCE (95.4%, LTL-15552A: 6541 ± 50 BP). Figure 2 reports $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ (‰) values from dentine increments (teeth 36, 37, and 38) and bone (left femur), covering the entire life of this individual. This individual displayed extensive enamel hypoplasia (EH) lesions, affecting 18 teeth, with estimated growth disturbances around 2, 2.5, 3, 3.8–4, 4.5, and 5.2–5.8 years old.

Tooth 36 shows a steep decline in $\delta^{15}N$ (‰) values indicating an abrupt transition towards solid food; an initial decline in $\delta^{13}C$ (‰) values also corresponds to the weaning period (Fuller et al. 2006) (Figure 2). After this, $\delta^{13}C$ and $\delta^{15}N$ (‰) isotopes suggest a stable composition of protein.

$\delta^{34}S$ (‰) values during weaning are lower than those obtained from the local fauna. Following this, $\delta^{13}C$ and $\delta^{34}S$ (‰) values are more variable than $\delta^{15}N$ (‰) values, and they appear to covary, increasing slightly from early to late childhood, followed by a drop and a subsequent rise with a peak around the beginning of adolescence.

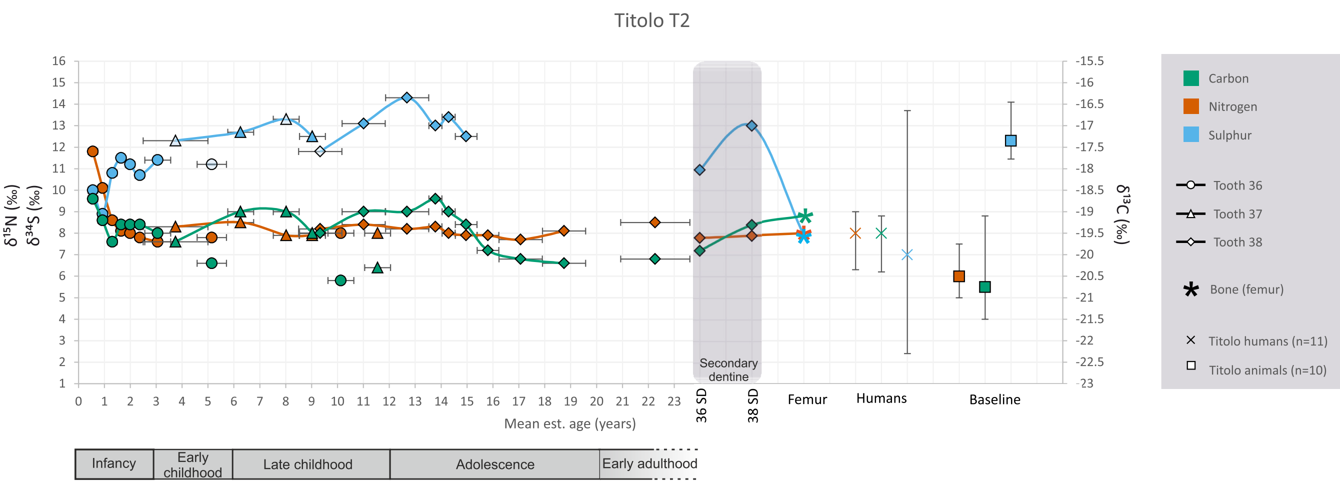

FIGURE 2 | $\delta^{13}C$ (dark green), $\delta^{15}N$ (red) and $\delta^{34}S$ (light blue) values of dentine increments from the lower left first (tooth 36, circles), second (tooth 37, triangles), and third (tooth 38, diamonds) molars and bone (stars) from individual T2 from Titolo (BA) according to estimated mean age intervals. Human bone values (crosses) and animal bone values (squares) from the site are also reported as median with min and max for comparison purposes. Semitransparent light blue symbols indicate samples that have %S, C/S, and N/S slightly outside the suggested range and therefore discussed with caution in the main text. [Colour figure can be viewed at wileyonlinelibrary.com]

Following this, $\delta^{13}C$ (‰) values in tooth 38 decrease during adolescence, also reflected in secondary dentine from tooth 36's root. Although we lack $\delta^{34}S$ (‰) values for the same time frame, those from adult bone are ^{34}S-depleted compared to values from dentine increments as well as local fauna (Figure 2), suggesting that T2 moved to a location more inland than Titolo in the years preceding their death. Human bone values (crosses) and faunal bone values (squares) from the site are also reported as median with min and max for comparison purposes.

3.2.2 | T3 From Titolo

The individual from Burial 3 is a probable male, estimated to be between 35 and 45 years old at death and radiocarbon dated to 5479–5363 cal BCE (95.4%, SUERC-106332: 6452 ± 29 BP). Only tooth 27 was available for incremental analysis, supplemented by one rib fragment to provide adult isotopic signatures. Thus, we have insight into their lifetime from ca. 2.5 to ca. 15 years old and then again from around a decade before their death. Their childhood had multiple growth disturbances; hypoplastic lesions in six teeth reflect growth disturbances around ages 3.3–3.6, 3.9–4, and 4.5 years.

Tooth 27 suggests that weaning must have already been completed before 2.5 years, because both the nitrogen and carbon curves appear flattened (Figure 3). This is followed by a gradual, temporary increase of $\delta^{34}S$ and $\delta^{13}C$ (‰) values, which peak around the transition from early to late childhood (Figure 3), whereas $\delta^{15}N$ (‰) values remain stable. Following this, we observe gradually lower $\delta^{34}S$ and $\delta^{13}C$ (‰) values and higher $\delta^{15}N$ (‰) values from the end of late childhood, culminating in adolescence (Figure 3).

The years before death are characterized by $\delta^{13}C$ and $\delta^{15}N$ (‰) values within the variability for the population of Titolo, but a much lower $\delta^{34}S$ value is present (2.4‰, approximately 8‰ lower than the fauna from Titolo and the values observed during childhood) (Figure 3). As with T2, such a ^{34}S-depleted isotope value suggests that T3 too was living somewhere more inland than Titolo in the years preceding their death.

3.2.3 | T6 From Titolo

The individual from Burial 6 is a male, estimated between 35 and 45 years old at death, radiocarbon dated to 5311–5045 cal BCE (95.4%, LTL-14541A: 6230 ± 50 BP). We sampled tooth 23, which showed some dental wear; thus, increments started around the age of 2 and continued to ~14 years old. Adult isotopic data came from a fragment of fibula. Six teeth from T6 displayed linear hypoplastic defects, estimated to have occurred around ages 3.5, 4, 4.5, and 5–5.5 years old.

Weaning appears to have been completed by about 2, as suggested by the flat nitrogen and carbon isotope curves (Figure 4). $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ (‰) values of the tooth and of the bone appear to be quite homogeneous throughout the period considered (Figure 4). $\delta^{34}S$ (‰) values are lower than the fauna from the site (approximately by 8‰), suggesting that this individual spent his life in a far more inland location compared to Titolo.

3.2.4 | T5 From Passo di Corvo

The individual from Burial 5 is an adult male (Mariotti et al. 2020), estimated between 18 and 25 years old at death. We sampled tooth 26, covering from ~0.4 to 9.5 years old from the tooth; a fragment of the right humerus provided data on the last decade of life. This individual displayed growth disturbances on nine teeth at estimated ages of 2.5–3.6 and again at around 5.5 years old.

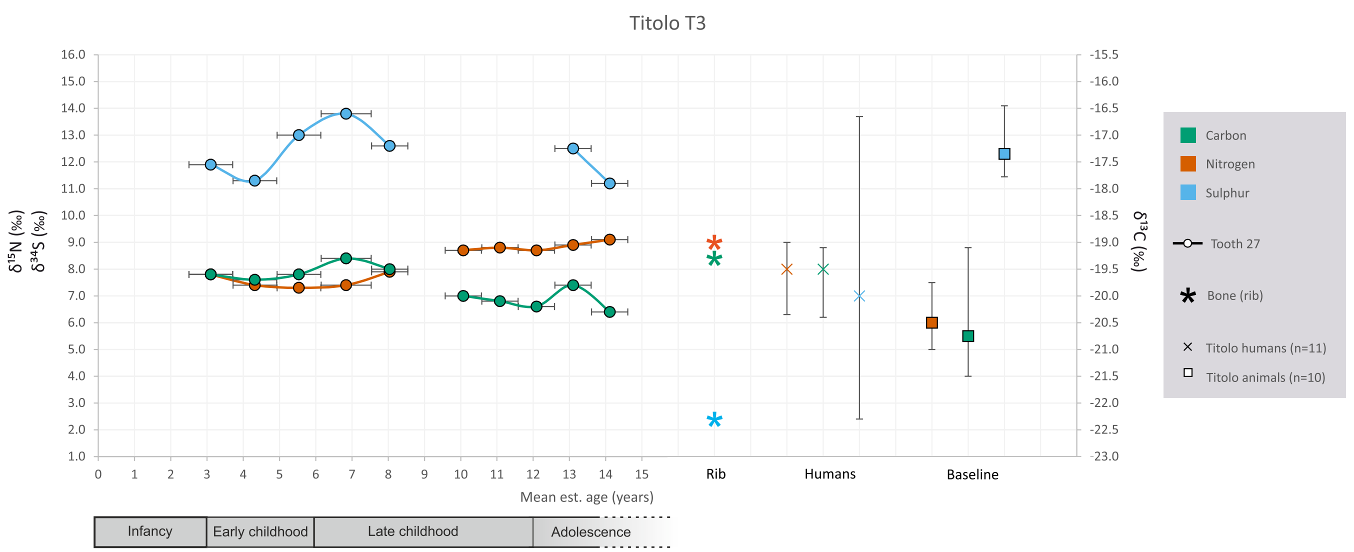

FIGURE 3 | $\delta^{13}C$ (dark green), $\delta^{15}N$ (red) and $\delta^{34}S$ (light blue) values of dentine increments from the upper left second molar (tooth 27, circles) and bone (stars) from individual T3 from Titolo (BA) according to estimated mean age intervals. Human bone values (crosses) and animal bone values (squares) from the site are also reported as median with min and max for comparison purposes. [Colour figure can be viewed at wileyonlinelibrary.com]

The second section of Tooth 26 shows increased δ^{15}N (‰), which corresponds with a minor increase in δ^{13}C (‰) and a minor decrease of δ^{34}S (‰) value (Figure 5). These variations are probably linked to changes in breastfeeding patterns. Weaning appears to be gradual and terminates during late infancy/early childhood. Interestingly, although nitrogen and carbon curves decline following weaning, the sulfur curve rises; this could potentially suggest the introduction of a food source during weaning, which is ^{34}S-enriched. δ^{34}S values remain higher in the later increments, potentially suggesting that this dietary source is maintained, although we consider other possible interpretations, including diagenetic alteration. The δ^{15}N (‰) value rises closer to their time of death (Figure 5).

3.2.5 | T11 From Passo di Corvo

The individual from Burial 11 is an adult, estimated between 18 and 25 years old at death, for whom osteological sex was not determinable (Mariotti et al. 2020). T11 presented EH lines on 14 teeth, attesting to numerous periods of stress between the ages of 2–6.8 years of age. We selected teeth 16 and 28 to cover the period from approximately 0.4 to 23.5 years old, to which we added a cranial fragment for later life values.

δ^{15}N and δ^{13}C (‰) values of Tooth 16 corresponding to early infancy indicate that weaning in this individual occurred more rapidly than in T5 (Figure 6) and was completed in early childhood. This period is followed by increased δ^{13}C (‰)

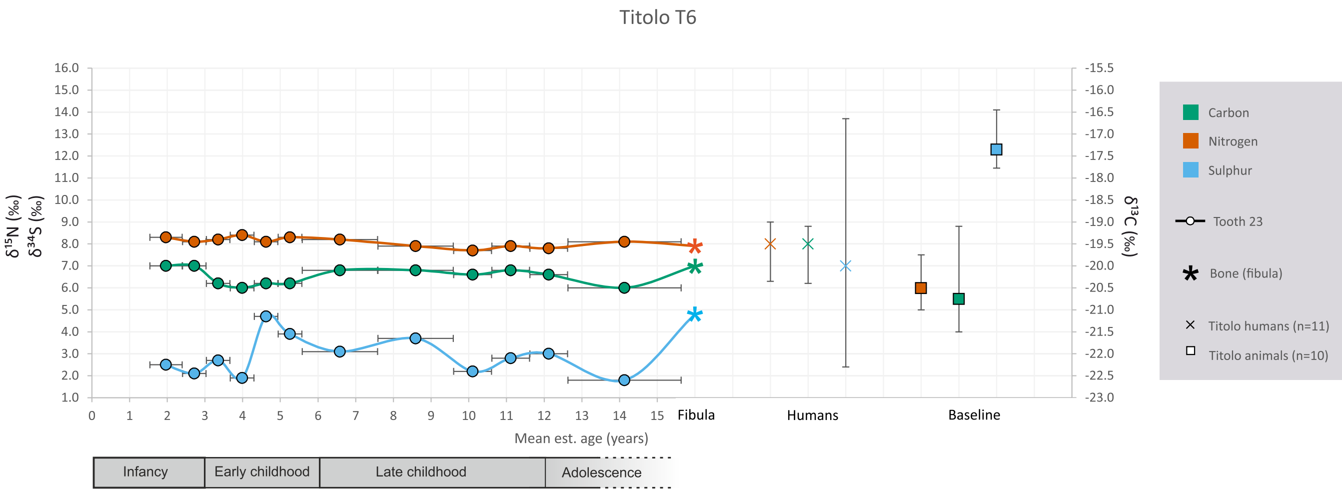

FIGURE 4 | δ^{13}C (dark green), δ^{15}N (red) and δ^{34}S (light blue) values of dentine increments from the upper left canine (tooth 23, circles) and bone (stars) from individual T6 from Titolo (BA) according to estimated mean age intervals. Human bone values (crosses) and animal bone values (squares) from the site are also reported as median with min and max for comparison purposes. [Colour figure can be viewed at wileyonlinelibrary.com]

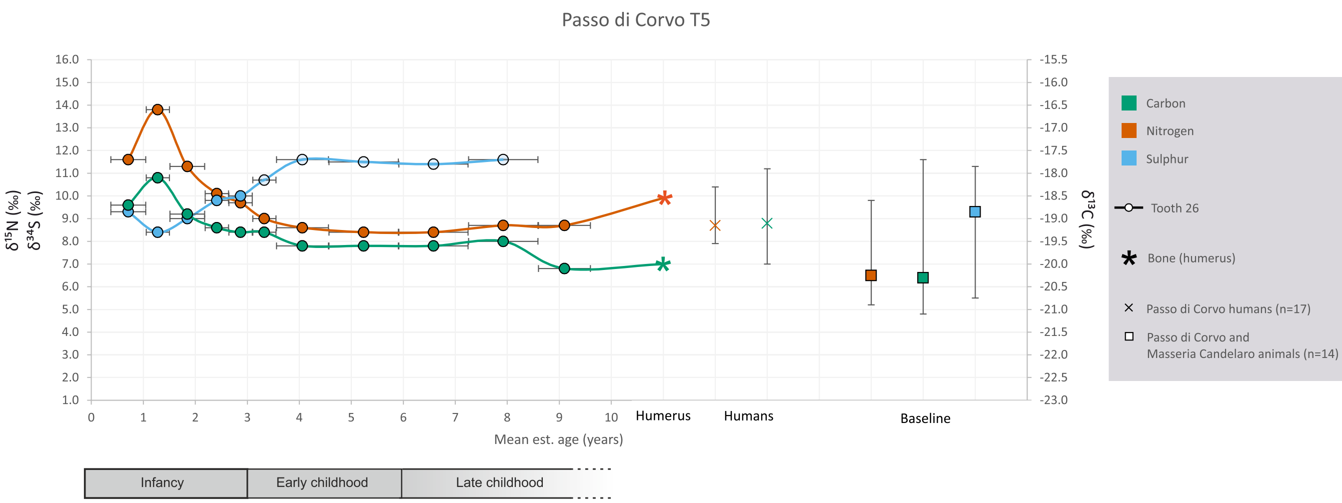

FIGURE 5 | δ^{13}C (dark green), δ^{15}N (red), and δ^{34}S (light blue) values of dentine increments from the upper left first molar (tooth 26, circles) and bone (stars) from individual T5 from Passo di Corvo (FG) according to estimated mean age intervals. Human bone values (crosses) and animal bone values (squares) from the site are also reported as median with min and max for comparison purposes. Semitransparent light blue symbols indicate samples that have %S, C/S, and N/S slightly outside the suggested range and therefore discussed with caution in the main text. [Colour figure can be viewed at wileyonlinelibrary.com]

values, with a peak of −19‰ around the end of early childhood. Interestingly, $\delta^{34}S$ (‰) values are higher than the local baseline values at least until late childhood (Figure 6).

The adult bone $\delta^{34}S$ value (10.5‰) is lower, in line with the local baseline. The carbon and nitrogen isotope curves decline starting around the transition from late childhood, across adolescence, up to the transition towards young adulthood (Figure 6). The bone signal shows increased $\delta^{15}N$ and $\delta^{13}C$ (‰) values, which at first sight appear to suggest increased consumption of animal products and/or manured plants but may also be the effect of the average signal accounting for the higher $\delta^{15}N$ and $\delta^{13}C$ (‰) values observed earlier in life.

4 | Discussion

These combined life histories point to several stages in the life course where dietary or mobility changes were experienced. First, there was flexibility in breastfeeding and weaning practices. Second, fluctuations in stable isotope values in childhood and adolescence point to a complex palimpsest that requires careful consideration. Additionally, at least some of these individuals exhibited mobility, likely involving both short- and long-distance relocations.

4.1 | Breastfeeding and Weaning

Breastfeeding and weaning behaviors were observed in Titolo T2 and Passo di Corvo (T5 and T11). T2 from Titolo exhibits the steepest decline of $\delta^{15}N$ (‰) values suggesting an abrupt introduction of solid foods during infancy (Figure 2). T5 and T11 from Passo di Corvo show initial $\delta^{15}N$ (‰) values indicating different breastfeeding and weaning practices. Indeed, this could be caused by different scenarios: T5 was breastfed close to birth, which was perhaps then interrupted and reintroduced; alternatively, their initial nurturer later changed, or they may have been breastfed by a nurturer who changed their diet while breastfeeding, after which T5 was gradually introduced to solid foods (Figure 5) (Scharlotta et al. 2018; Ganiatsou et al. 2022). T10bis also appears to have been weaned gradually (Supporting Information; Figure S19). The quickest transition towards solid food was in T11 (Figure 6). Most individuals (Titolo T2 and T6; Passo di Corvo T10bis, T11 from Passo di Corvo) show $\delta^{15}N$ values in dentine consistent with their bone collagen. However, others show slight dips postweaning (T3 from Titolo and T5 from Passo di Corvo), suggesting variability of early-life dietary practices even within the same site (Goude et al. 2020).

Also noteworthy is the initial decline in stable sulfur isotope values during infancy among individuals T2 from Titolo and T5 and T11 from Passo di Corvo. This decline is followed by either a pronounced (T2 from Titolo and T11 from Passo di Corvo) or a gradual rise (T5 from Passo di Corvo) in the curve during weaning, as evidenced by $\delta^{15}N$ and $\delta^{13}C$ (‰) values. One possible explanation would be that there was a food source that was not present in the diet of the nurturer but that was introduced into the child's diet during weaning; this source is characterized by more ^{34}S-enriched $\delta^{34}S$ (‰) values and could therefore be represented by marine organisms. Fish is cited as a dietary taboo during pregnancy in some agricultural societies (Maggiulli et al. 2022), and some societies keep food taboos among lactating women (Meyer-Rochow 2009). Hence, it is a possibility that caregivers of these children might have avoided the consumption of aquatic resources. It is plausible that aquatic resources could have been introduced during the weaning process (Nehlich et al. 2011; Cheung et al. 2022). Overall, it is especially interesting that we note the absence of apparent norms in terms of breastfeeding and weaning behaviors at both sites.

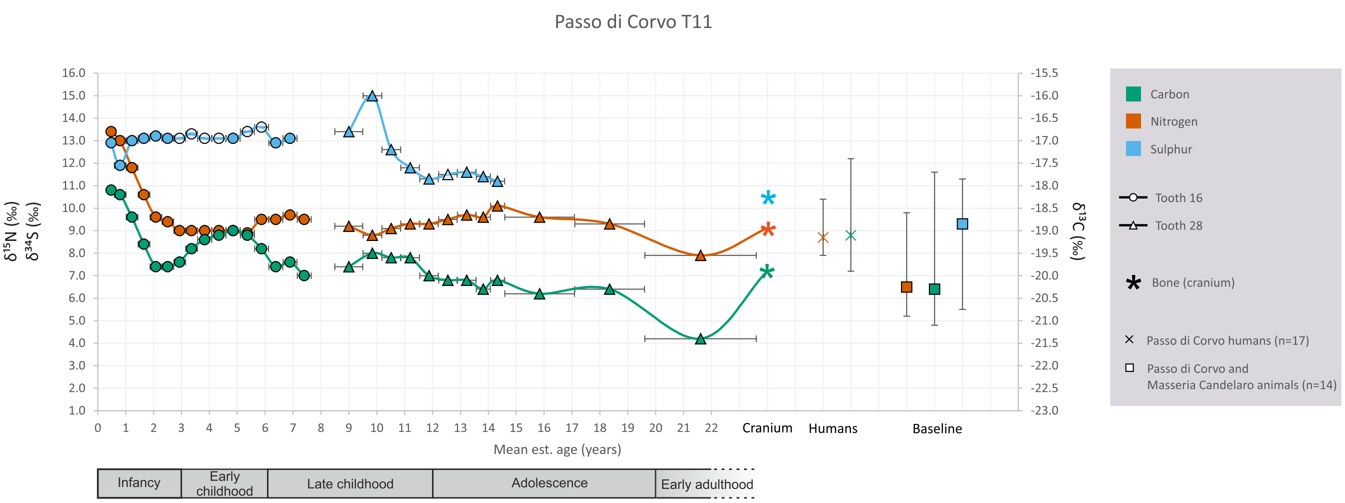

FIGURE 6 | $\delta^{13}C$ (dark green), $\delta^{15}N$ (red), and $\delta^{34}S$ (light blue) values of dentine increments from the upper right first (tooth 16, circles) and upper left third (tooth 28, triangles) molars and bone (stars) from individual T11 from Passo di Corvo (FG) according to estimated mean age intervals. Human bone values (crosses) and animal bone values (squares) from the site are also reported as median with min and max for comparison purposes. Semitransparent light blue symbols indicate samples which have %S, C/S, and N/S slightly outside the suggested range and therefore discussed with caution in the main text. [Colour figure can be viewed at wileyonlinelibrary.com]

4.2 | Variations in Diet During Life, Physiology, or Mobility?

Among the individuals analyzed, we observed occasional yet recurring fluctuations in stable isotope values during childhood and adolescence. These are challenging to interpret but indicate some sort of adaptation throughout portions of their early lives. These frequently involve sulfur, sometimes accompanied by carbon and nitrogen (T2 and T3 from Titolo and T11 from Passo di Corvo). Notably, what stands out is the enrichment in $\delta^{34}S$ values often beginning during the weaning period and persisting into childhood, albeit with minor fluctuations (T2 and T3 from Titolo and T5 and T11 from Passo di Corvo). Although these fluctuations may reflect dietary inputs from marine or lagoonal resources, growth-related metabolic effects, or short-range mobility, disentangling these influences remains challenging due to overlapping ecological and physiological factors (see detailed discussion, Supporting Information).

4.3 | Long-Range Mobility in Neolithic Puglia

Sulfur isotope values of dentine increments compared to those from bone provide strong evidence for long-range mobility at Titolo. T2 and T3 must have spent their adulthoods more inland, because their bone signals exhibit highly ^{34}S-depleted values compared to those observed in their dentine increments and in local fauna, clearly either they returned to Titolo sometime before their deaths or perhaps they were transported there after death to be buried there. In contrast, T6 exhibits stable sulfur isotope values of dentine increments typical of an inland location, suggesting that they spent their childhood and adolescence far away from Titolo. It is possible that they relocated to Titolo a short time before death but long enough to experience some collagen turnover, which would explain slightly higher $\delta^{34}S$ (‰) values in the bone element.

How far away is “more inland”? Answering this question is challenging due to limited regional $\delta^{34}S$ (‰) data and the complex interplay of diet, sea spray, and geology. However, the faunal assemblage from Passo di Corvo, which is located more inland than Titolo, is only slightly lower ($\delta^{34}S$ mean: 9.7 ± 1.4‰) than that from Titolo, which is directly located on the coast ($\delta^{34}S$ mean: 12.1 ± 1.9‰). Therefore, the observed differences at Titolo likely indicate movement to much more distant inland areas (> 25–50 km inland) or areas with distinct local geology. Notably, this pattern of migrating to and from an inland area, only to return to Titolo for their final years or even posthumously, persisted across generations (see the Supporting Information for a radiocarbon date model; Table S1 and Figure S1). People might have chosen to move for a variety of reasons; the circulation of materials is well documented archaeologically, but we can also imagine kinship and family ties, responses to local environmental fluctuations, the social trajectories of particular settlements, and other motives.

4.4 | Limitations of the Study

Our study serves as an initial investigation, albeit with inevitable limitations. Although the incremental dentine approach provides insights into individual life courses that can greatly enrich our understanding of past societies, we recognize the need for caution in interpreting ages associated with specific events. Additionally, bulk $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ (‰) of both bone and teeth are often difficult to interpret, as these values and their fluctuations might be caused by a number of factors. For example, we proposed that marine or lagoonal resources might have been introduced during weaning and in other moments of their life, but they might also be indicative of other reasons (see a detailed discussion around this in the Supporting Information). Higher resolution approaches, such as stable isotope analysis of amino acids in dentine increments, are needed to explain these fluctuations in greater detail. It is important to note that our study is limited to only five individuals, and for reasons of availability of material and to avoid more extensive destructive sampling as per our ethical criteria, none were females. This study therefore excludes investigation of possible gender-related differences in life histories. Finally, incorporating Neolithic individuals from inland sites could provide valuable insights into mobility dynamics within these regions and their interactions with coastal areas.

5 | Conclusion: Isobiographies and Microvariation

Overall, the isobiographical data obtained indicate unexpected complexity in the life narratives of early communities in Neolithic Puglia. From birth to death, dietary patterns and residential mobility are far from homogeneous; they might have been the result of personal histories, family ties, and socioeconomic constraints. These insights offer a deeper understanding of lifeways within Neolithic communities, which are otherwise invisible using the traditional bulk stable isotope approach of bone elements. Specifically, we highlighted variability in the breastfeeding and weaning practices among these communities, with an apparent absence of fixed norms. We have further observed that the typical dietary “Neolithic package” may have undergone occasional modifications for certain periods of life as a response to climatic, environmental, or even nutritional and physiological constraints. Further research, such as stable isotope analysis of amino acids in dentine increments, is needed to explore these fluctuations in greater detail. Our findings also shed light on mobility patterns within Neolithic Puglia. The stable sulfur isotopic evidence hints at short-range mobility for some individuals, such as those from Passo di Corvo, who may have spent their childhood in nearby villages closer to the coast. Conversely, stable sulfur isotope values of individuals from Titolo point towards connections to more distant locations. Following recent evidence that dietary habits varied locally according to environmental constraints or even to cultural identities, here, we have shown that such variation is also reflected at the individual level. Life histories differ considerably from one individual to another, even within the same community.

Author Contributions

Silvia Soncin: conceptualization (equal), data curation (lead), formal analysis (lead), investigation (lead), methodology (equal), visualization (lead), writing – original draft preparation (lead), writing – review and editing (equal). **Sofia Panella:** formal analysis (equal), investigation (supporting), methodology (equal), visualization (equal), writing – original draft preparation (equal), writing – review and editing (equal). **Sara Bernardini:** formal analysis (equal), investigation (equal), methodology (equal), visualization (equal), writing – original draft preparation (equal), writing – review and editing (equal). **Jess Emma Thompson:** formal analysis (equal), investigation (supporting), methodology (equal), visualization (supporting), writing – original draft preparation (equal), writing – review and editing (equal). **Gwenaëlle Goude:** supervision (supporting), writing – review and editing (equal). **Martina di Matteo:** formal analysis (equal), writing – review and editing (equal). **Francesca Alhaique:** formal analysis (equal), resources (equal), writing – review and editing (equal). **Krista McGrath:** formal analysis (equal), writing – review and editing (equal). **Francesca Radina:** resources (equal), writing – review and editing (equal). **Sandra Sivilli:** resources (equal), writing – review and editing (equal). **Maria Giovanna Belcastro:** formal analysis (equal), resources (equal), writing – review and editing (equal). **Valentina Mariotti:** formal analysis (equal), resources (equal), writing – review and editing (equal). **John Robb:** funding acquisition (lead), writing – original draft preparation (equal), writing – review and editing (equal). **Mary Anne Tafuri:** conceptualization (equal), funding acquisition (lead), supervision (lead), writing – original draft preparation (equal), writing – review and editing (equal).

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available in the Supporting Information.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.