

Stable isotope analysis of the dietary habits of a Greek community in Archaic Syracuse (Sicily): a pilot study

Davide Tanasi ^a, Robert H. Tykot ^b, Andrea Vianello ^b and Stephan Hassam^a

^aCenter for Virtualization and Applied Spatial Technologies (CVAST) & Department of History, University of South Florida, 4202 E Fowler Ave, Tampa, FL, US; ^bDepartment of Anthropology, University of South Florida, 4202 E Fowler Ave, Tampa, FL, US

ABSTRACT

The study and reconstruction of ancient dietary habits has become a very significant topic in archaeological research. Most chemical analysis studies for diet at Greek sites are limited to prehistory, with very few examples of studies for the Classical period. This paper represents a pilot study of stable isotope analysis carried out on a group of 15 individuals selected among the population interred in the Archaic necropolis of Scala Greca at Syracuse (Sicily), a cemetery discovered in 2010-2011. Based on the funerary assemblages and certain features such as shape, dimensions, coverage system and architectural features, a preliminary distinction has been made based on apparent wealth on a diagnostic sample of 15 tombs to test possible variations in diet. Carbon and nitrogen isotope analyses were conducted on bone collagen, which represents dietary protein, and bone apatite, which represents the whole diet. The highly negative collagen carbon isotope values indicate little if any seafood in the diet, and this is supported by the nitrogen isotope modest values, which are consistent with terrestrial foods and do not suggest higher trophic level fish.

KEYWORDS

Greek Sicily; necropolis; social hierarchy; stable isotope analysis; carbon; nitrogen

1. Introduction

The technique to reconstruct ancient diet using stable isotopes is well documented (e.g. Schoeninger 2011) and its use has been tested across the world. At its core, the study of isotopes is based on a correlation between the carbon isotope ratio in bone collagen and in bone apatite, as well as the carbon isotope ratio in diet, and between nitrogen isotope ratio in bone collagen and the ratio in diet (Schoeninger 2011: 445). The values obtained can be better interpreted if animal bones from the same area and a similar period are also tested, something that unfortunately was not possible for our study. Consumption of fish, particularly marine fish, is nevertheless usually easy to detect due to a spike in nitrogen isotope ratio values. The field of stable isotope analyses has progressed over the last couple of decades, allowing some inferences on nutrition, health and paleopathology (Reitsema 2013: 450-453).

The abundance of literary and iconographic sources about culinary and dietary habits of ancient Greeks has not spurred an interest among scholars to scientifically test our presumed knowledge. At the same time, the absence of recent excavations in Greece, Magna Graecia and Sicily, of a scale and scope that would include stable isotope analyses, has resulted in no significant advancement for these studies applied to Archaic and

Classical Greece contexts. “Greece today is one of the most systematically examined and best-documented places in the world” claimed Papathanasiou and Fox (2015: 5), but this statement is not valid for our period. Although there are recent studies focusing on food in antiquity covering the regions frequented by the Greeks, research on this topic is still sparse at best, and only offers tantalizing hints at what may become possible with larger datasets. Lagia, Papathanasiou and Triantaphyllou (2014: 115, table 8.1) report 19 Classical period sites investigated in Greece, and these include more than diet and nutrition studies through $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ stable isotope analysis. We have only a few comparable examples that we summarize here, focusing particularly on the variability of diet at any one site and any ‘typical’ diet that may have been recognized.

Anna Lagia (2014, 2015a, 2015b) has focused some of her research on a few cemeteries in Athens and Laurion (Kerameikos, Plateia Kotzia and Laurion) in a diachronic study spanning from the Classical to Roman periods. The diet of the Classical period was primarily based on consuming terrestrial C3 plants, with some contributions from animals and minimal presence of marine food, but it was overall very good and better than in the later periods. The data suggests comparable values from the cemeteries of

Kerameikos and Plateia Kotzia, with one outlier from Laurion. Nitrogen isotope ($\delta^{15}\text{N}$) values show a broader range during the Classical period than in later periods, and might be associated with fish consumption. It is observed that Classical Athens shows a significant increase in consumption of animal proteins, which is higher than values found at Classical period Makriyalos (Lagia 2015b: 135-136). In Italy, a study of 48 individuals from Metaponto (7th to 2nd centuries BC) has shown a diet consistent with consumption of C3 plants and some animal proteins, but it was also possible to differentiate between urban and rural individuals, showing a diet richer in proteins in urbanized individuals (Henneberg & Henneberg 2003).

A further study, focusing on Classical Thebes (Vika, Aravantinos, & Richards 2015), shows similar values to Metaponto, Athens and Makriyalos, but with a statistically significant increase in $\delta^{15}\text{N}$ values interpreted as evidence of consumption of freshwater fish in the area, a view supported also by historical sources (Vika, Aravantinos, & Richards 2015: 1080). Vika (2011) has carried out a diachronic study, showing that the consumption of freshwater fish in Classical Thebes decreased in the Hellenistic period, even if fish remained present in the diet, unlike in individuals from Bronze Age contexts. The same pattern has been observed for Athens, which shows a diet richer in proteins limited to the Classical period (Lagia 2015b). The question of (freshwater) fish consumption in Classical Greece has been the focus of several papers, and targeted analyses have been carried out on human and fish bones to quantify its presence (Vika & Theodoropoulou 2012; Vika, Aravantinos, & Richards 2015). The results at the Classical site of Thebes show that fish consumption may have been more abundant than previously thought because of the increase in the $\delta^{15}\text{N}$ of several human values, and further refinements have strengthened the case for freshwater fish consumption.

Classical Apollonia (Keenleyside, Schwarcz & Panayotova 2006), in the Black Sea, is also important to mention for comparative purposes, being a Greek colony like Syracuse. Here the typical diet consisted of C3 plants integrated by animal proteins, but marine fish could be detected in the samples as well. The authors used modern marine samples from the Mediterranean rather than from the Black Sea, and this could produce a future revision on the statistical significance of fish in the analyzed samples. The results appear also quite clustered, and the authors note that despite differences in grave pits, no variation could be detected according to burial type (Keenleyside, Schwarcz & Panayotova 2006: 1212), and social status does not seem to have played a role in diet, a conclusion also shared by Lagia in her study of the cemeteries in Athens.

2. Archaeological context

The data that follows is what could be collected, and is incomplete but for the study of major artifacts associated with the tombs. We believe that some data are better than no data, and the contextual information does not affect our main research question on the (social) variability of the burials as determined by assemblages and dietary reconstruction. At the time of the study no faunal, archaeobotanical or anthropological study had been carried out.

During an infrastructural project in a plot of land in Syracuse (Fig. 1), between Viale Scala Greca and Viale Santa Panagia, the Superintendency of Cultural Heritage of Syracuse discovered portions of a large cemetery, mainly composed by rock-cut fossa (pit) graves. The exploration, carried out between November 22nd 2010 and March 11th 2011, led to the identification of 135 burials, organized in four spatial groups (Tanasi, Lanteri & Hassam 2016) (Figs. 2–3).

The cemetery develops from west to east for 180 meters, with the last tombs identified on the eastern edge about 250 meters from the most western ones of the Viale Santa Panagia necropolis. It seems highly probable that this area is the westward continuation of the cemetery of Santa Panagia. Considering that the concentration of graves in western Groups I and II of Viale Scala Greca is very loose, it may be possible to suggest that those groups represent the outskirts if not the limit of a cemeterial belt ranging from the so-called “Muro di Gelone” to the east, and the current Viale Scala Greca in the west, for a total length of 700 meters. In the Archaic period, this complex should have represented a blockage marking the end of the urbanized area on the northern side.

The central part of the identified necropolis of Viale Scala Greca was found to be intercepted by the cut of a quarry, probably established at the beginning of the past century, which destroyed several tombs creating a topographic gap in the articulation of the cemetery. Traces of the same quarry were also reported during the earliest excavation of the tombs in Viale Santa Panagia/Via Mazzanti/Via Bulgaria (Gentili 1961: 406).

In 2013 an interdisciplinary project, designed with the overall study of this archaeological evidence in mind, was undertaken by one of the authors (Tanasi) in partnership with the Superintendency of Cultural Heritage of Syracuse. The data presented in this contribution may offer a new perspective on the study of Archaic funerary practices and supplement the current state of knowledge. Although the detailed presentation of the archaeological context was the subject of another publication (Tanasi, Lanteri & Hassam 2016), it would be beneficial for our discussion to recall here the main features of the Scala Greca necropolis.



Figure 1. Location of Syracuse in the Mediterranean Sea.

With regards to tomb typologies and burial practices of the 135 graves, 117 are rock-cut *fossae* (pits), 15 are cremations with ashes collected into amphorae, one is a cremation inside a fossa and two are tile graves. Besides the 117 well-preserved *fossae*, 10 others were nearly completely destroyed by the quarry.

The rock cut *fossae*, or pit graves as they are more often called, are certainly the most common. The intact *fossae* were covered by three or four massive stone slabs set in place with stone debris and small rocks. Some others have a row of stone blocks set along one side in order to make the tomb wall even with the opposite



Figure 2. Aerial photo indicating the two cemetery complexes of Viale Santa Panagia/Via Mazzanti/Via Bulgaria (excavations 1959, 1988-1999, 2002) and Viale Scala Greca (excavations 2010-2011).

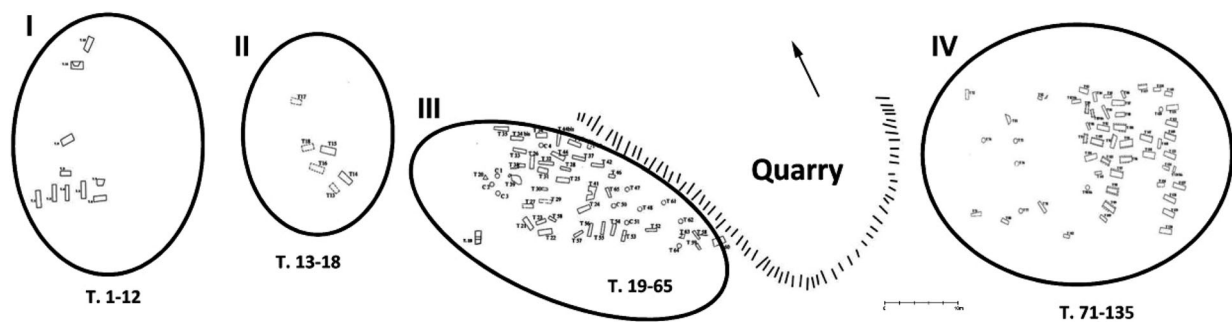


Figure 3. General plan of the necropolis with indication of the four groups.

side that is carved into the bedrock at a higher level. More rarely a wall was built on both the long sides of the tomb. With respect to the dimensions of the pit graves, it has been possible to group them on the basis of the 98 better preserved examples as follows (Tab. 1, Chart 1). The average depth of the tombs ranges between 65 and 40 cm, with the exception of tomb 22 (80 cm) and tomb 23 (10 cm).

Regarding the shape and architectural features of the pit graves, all of them have a rather rectangular shape with the exception of 16 tombs which were instead very irregular in shape. Fourteen graves show a ledge carved all around the inner perimeter of the cut in

order to place stone slabs or tiles used as cover (Fig. 4). In three cases (tombs 9, 122, 135) three large and thick stone rectangular slabs were found *in situ*. Nineteen tombs not showing any carved ledge were covered with stone slabs as well. In one case (t. 20), the tomb's two terracotta tile covers were found intact. In all the other cases, due to results of activities carried out in the field where the necropolis lies, it was not possible to clearly detect the system of coverage as the topsoil was altered down to the height of the tombs

Among the best preserved pit graves, 66 produced grave goods (Figs. 5–8). The majority of the grave goods in the pit graves are represented by pottery, often consisting of lekythoi and skyphoi, followed by less common shapes such as the kylix, olpe, guttus, pixis with lid, askos, aryballos, lamp, lekane, oinochoe and stamnos (Tanasi, Lanteri & Hassam 2016) (Fig. 8).

A number of tombs also produced terracotta figurines of different types: figurines of standing women with braids or high polos, rough and undifferentiated figurines with hands clasped over the chest, as well as figurines of animals, mostly horses and birds. Peculiar is the case of the partly preserved figurine of a knight on horseback, from tomb 120, which is mirrored by other similar pieces found in a tomb of the Viale Santa Panagia necropolis (Guzzardi 2003: 42) and in tomb 122 of the Ex Giardino Spagna necropolis (Orsi 1925: 303-304).

Table 1. Pit graves regrouped on the basis of dimensions.

Dimensional range in cm (length x width)	Tombs	Total number
80/95 × 40/45	23, 30, 38, 46, 66, 82bis, 86, 89bis, 90, 91, 124bis, 125	12
100/115 × 35/50	67, 68, 72, 80, 84, 85, 89, 101, 103, 116, 118, 119, 124, 126, 131, 135	16
120/135 × 45/60	3, 27, 31, 81, 82, 88, 108	7
140/155 × 40/55	40, 53, 57, 65, 83, 99	6
160/175 × 40/70	4, 5, 6, 9, 11, 12, 21, 25, 26, 28, 32, 33, 36, 37, 42, 49, 52, 54, 55, 60, 71, 78, 94, 104, 109, 132	26
180/195 × 40/80	1, 2, 14, 16, 22, 24, 29, 34, 34bis, 35, 44, 56, 69, 70, 87, 92, 95, 96, 98, 105, 106, 107, 110, 111, 115, 121, 123, 128, 130	27
200/240 × 65/80	15, 97	2

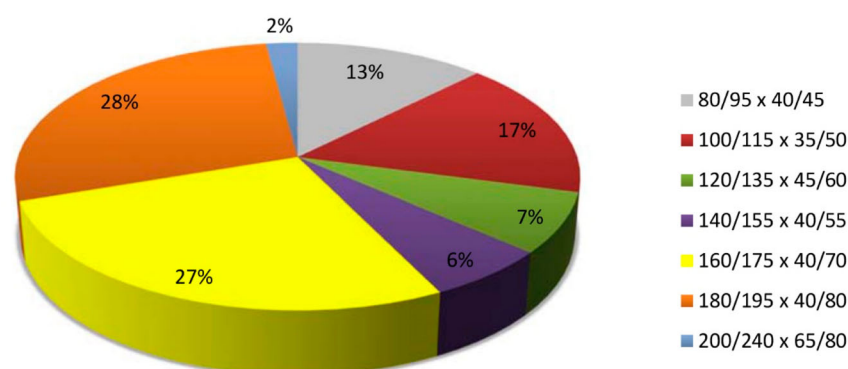


Chart 1. Dimensional groups of the chamber tombs (measurements in cm).

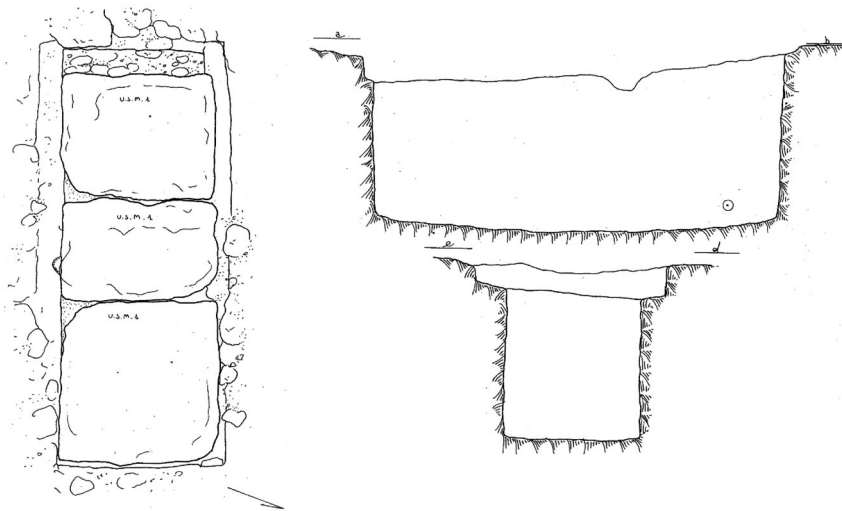


Figure 4. Plan and section view of tomb 100 showing the system of coverage with stone slabs placed above the inner ledge (not to scale).

With regards to metalwork, the evidence is rather unremarkable. Bronze sewing needles are quite common and also attested frequently at the Viale Santa Panagia necropolis (Guzzardi 2003: 42). Without anthropological analyses it is difficult to categorize these objects as belonging to female or male burials, however previous studies pointed to an association between such needles and female burials (Pelagatti & Voza 1979: 379). A rather interesting find is the iron sword found in tomb 70 (Fig. 9). It is a short sword,



Figure 5. Tomb 5, from north

0.45 m in length, with an iron hilt that was recovered along with two large iron rings, presumably used to attach it to a belt in place of a proper scabbard. Found along the left side of the skeleton, the sword was the only object placed in the tomb, possibly an indicator of social status for the deceased. The discovery of weapons in the Archaic period cemeteries of Syracuse is quite unusual (Pelagatti & Voza 1979: 375). In the preliminary report of the Viale Santa Panagia cemetery there is a generic reference to weapons for tombs 87, 98, 136, 152, 251 but it is not specified what type of weapons they are (Guzzardi 2003: 41). Besides those two references, no further data are available in the scientific literature due to lack of fieldwork. Therefore, this iron sword from the necropolis of Scala Greca is the first known so far for Archaic Syracuse.

Besides the pottery, terracottas, and metalwork, it is worth mentioning the two alabastra made of alabastron found in tombs 1 and 14, perfume containers sometimes associated with infant burials (Lambrugo 2005) and probably imported due to the lack of active alabastron caves in Greek Sicily. In tomb 1, the vessel was found placed upside down by the right shoulder of the skeleton and it was associated with a bronze buckle, possibly in relation to a belt. In tomb 14, it was placed upright by the left shoulder of the deceased and was found with a lekythos that was placed on the chest of the skeleton.

Besides 52 graves which had no grave gifts, considering that the majority of the tombs produced between 1 and 2 grave goods, the assemblages of tombs 90 (8 items), 126 (9 items) and especially 86 (10 items) seem to point to a higher rank for those three individuals. But at the same time, the small size of the tombs (126: 112 × 050 cm, 90: 97 × 38 cm; 86: 96 × 41 cm) suggests that they were probably used to bury juvenile individuals who passed away before their time, as has been demonstrated in other cases (Pelagatti & Voza 1979: 374-375). The two alabastra could instead testify



Figure 6. Tomb 22, from west.

to the ability of the deceased or their kin to acquire ‘exotic’ objects, potentially expensive due to the material with which they were made. This ability could be connected with their wealth or their work or the identity they wanted to assume and in any case such rare objects would be an appropriate synthesis of their life experiences (Whitley 2002). ‘Exotic’ here is understood as rare, uncommon, and is an easy measure to determine the possible ‘wealthy’ status of a burial. There is no implied correlation between deposited artifacts and wealth or social status for such a small sample, and limited study. Equally, the assumptions on the activities carried out in life by the buried individuals are ‘educated guesses’: we want to demonstrate a significant variability among the individuals buried in the same cemetery. Even the sword is not sufficient to determine the gender of the buried, let alone the individual’s occupation in life, but it is a fact that the sword was valuable, and is not a common grave good at the cemetery. On the other hand, the 27 pit graves found intact with well-preserved skeletons but without any sort of grave goods, scattered in groups I, III and IV of the cemetery, lead us to ascribe a low social status to these individuals.

The excavation of the necropolis did not produce any faunal or paleo-botanic data, and as the anthropological study of the skeletal remains is still ongoing, there is no information about age/sex, stature, or age at death of the population of the cemetery.

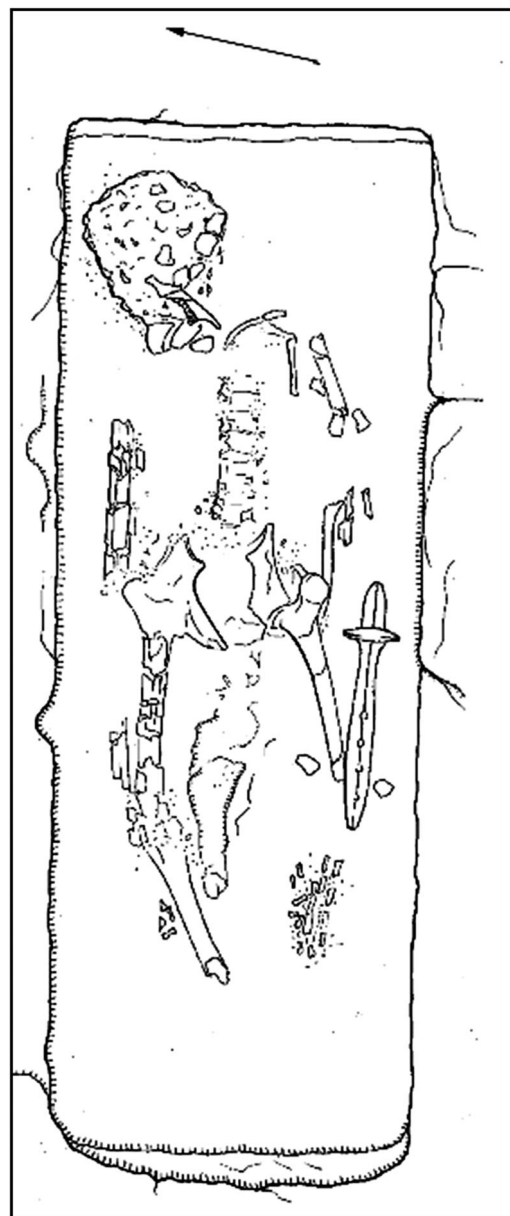


Figure 7. Plan of tomb 70 (not to scale).

However, as part of the post-excavation studies, it was decided to undertake a pilot study of stable isotope analyses aimed at reconstructing dietary habits of the community interred at Scala Greca.

A group of 15 individuals were selected as representative of supposedly wealthy/average/poor tombs using the number of items in the funerary assemblage and the architectural features as parameters for this determination (Table 2). The assumption was that tombs with no funerary assemblage or just one grave gift and with an irregular shape and no characterizing architectural features were considered ‘poor’ and those with 2 or more objects or 1 or more ‘exotic’ object (the iron sword for example) and with characterizing architectural features were to be interpreted as ‘wealthy’. No particular correlation emerged between dimensions, architectural features and number of objects. Specifically, individuals from tombs 28, 40, 42, 44bis, 49, 52, 54, 57, 69, 70, 78, 95, 98, 99, 107

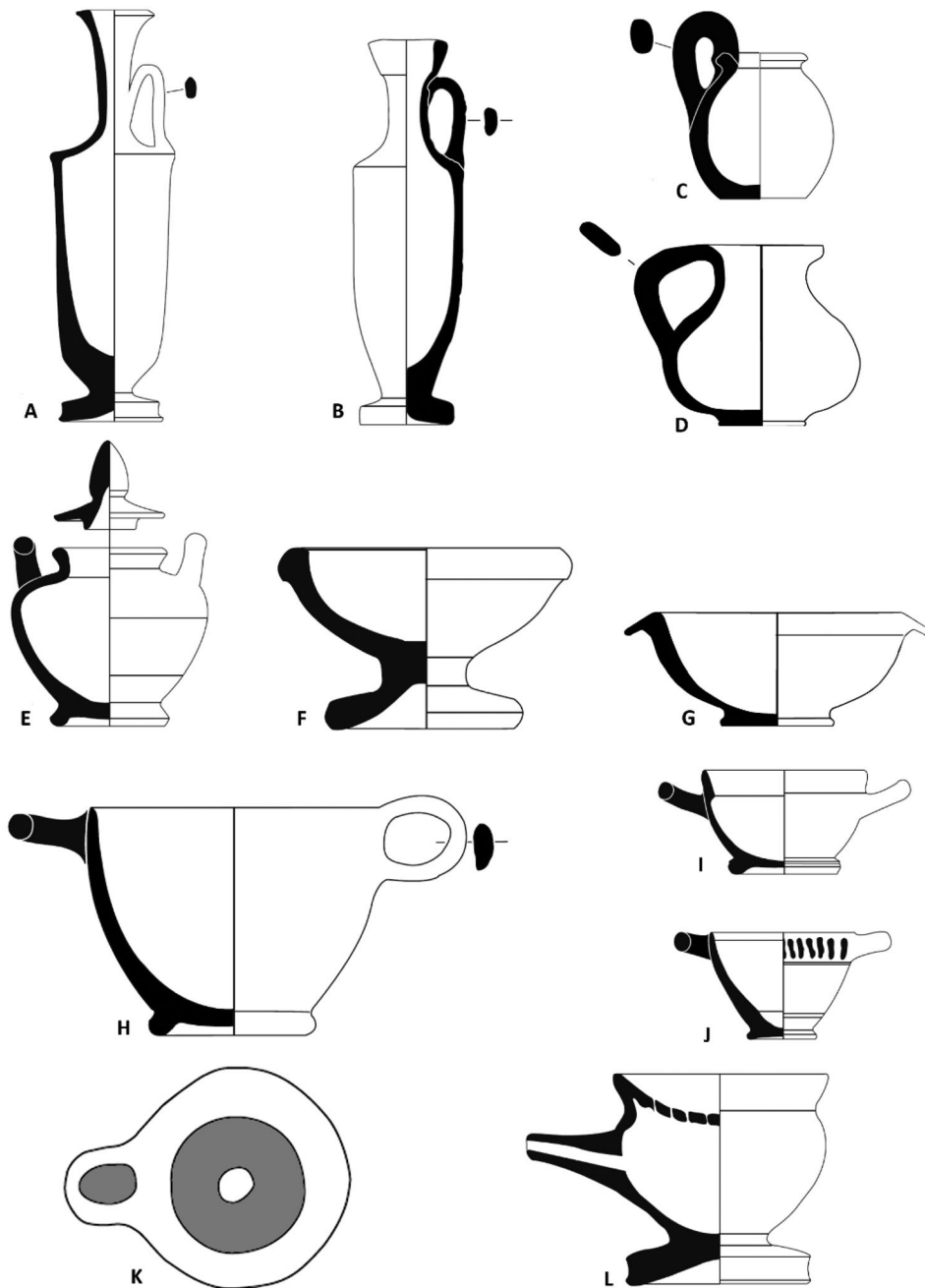


Figure 8. Overview of the principal ceramic shapes attested in the fossae, scale 1:3 (drawing S. Hassam).

were sampled and carbon and nitrogen isotope analyses conducted, to test the hypothesis that “wealthy” individuals would have had access to a protein rich and varied diet unlike others. The sample size is certainly insufficient to support any certain correlation, but if both grave goods and diet vary, then a hypothesis linking social status, grave goods and diet may be formulated and tested in future research.

3. Materials and methods

The analyses have been done on both collagen and apatite of bone material sampled by the authors from stored skeletal material often still encased in the original mud present at the discovery (anthropological analyses, even the most basic, were therefore

impossible; only a cursory check for artifacts was possible). The poor preservation of some bones has caused some problems in the preparation of the samples for the analyses, requiring more time to retrieve sufficient material to make possible the analyses, and even after much attention, two analyses have yielded no results. The analysis attempted here is necessarily incomplete of much data typically presented in similar studies because there are no



Figure 9. Tomb 70, iron sword and two iron rings.

Table 2. The group of 15 sampled individuals with the status hypothesized on the basis of the funerary assemblage of the tombs.

Tomb	Number of objects	Type of objects	Dimensions	Architectural features	Hypothesized status of the dead
28	6	Rep. 41 Askös Rep. 42 Skyphos Rep. 43 Olpe Rep. 44 Lekythos Rep. 45 Guttus Rep. 46 Skyphos	160/175 × 40/70 cm	Ledge just on one side	Wealthy
40	2	Rep. 62 Lekythos Rep. 63 Bronze needle	140/155 × 40/55	Ledge	Wealthy
42	0	Empty	160/175 × 40/70 cm	Irregular shape	Poor
44bis	1	Bronze needle	180/195 × 40/80 cm	Irregular shape	Poor
49	0	Empty	160/175 × 40/70 cm	Irregular shape	Poor
52	0	Empty	160/175 × 40/70 cm	Irregular shape	Poor
54	1	Bronze needle	160/175 × 40/70 cm	Irregular shape	Poor
57	0	Empty	140/155 × 40/55	Irregular shape	Poor
69	0	Empty	180/195 × 40/80 cm	Ledge	Poor
70	1	Iron sword	180/195 × 40/80 cm	No particular features	Wealthy
78	0	Empty	160/175 × 40/70 cm	Very shallow	Poor
95	3	Rep 41 Lekythos Rep 42 Terracotta figurine Rep 43 Skyphos	180/195 × 40/80 cm	No particular features	Wealthy
98	3	Rep 54 Lekythos Rep 55 Skyphos (?) Rep 56 Bronze tweezer	180/195 × 40/80 cm	Stone slabs	Wealthy
99	1	Rep 53 Cup	140/155 × 40/55	Irregular	Poor
107	1	Rep 57 Skyphos	180/195 × 40/80 cm	Irregular	Poor

anthropological analyses available. The present study wishes to bring the discoveries at the cemetery to the attention of the scholarly community and provide some data from a first study, which in practice was constrained by time limits in accessing the materials and funding limits. It is not unusual for countries such as Italy and Greece to store significant assemblages without much study due to funding constraints or archaeologists busy researching previous assemblages. It is essential to understand that the present study was borne out of opportunity, a preliminary test on stored materials that require much greater efforts. We have incomplete data, but our main aim was to test if the apparent variability in assemblages and tomb sizes is mirrored also in the diet, opening the possibility that the cemetery contains people of different social status and wealth. In particular, the choice of 15 burials has been determined by:

1. Limits on available funding for stable isotope analyses
2. The intention of representing the three main types of assemblages recognized, i.e. nothing or negligible artifacts, average, and significant or unusual artifacts (exotica, rare artifacts present)
3. Accessibility of skeletal materials, which could be incomplete, mixed, already stored for long-term conservation, encased in mud, or compromised by artifact extraction.

The samples were obtained on location in Syracuse, from skeletal materials found in individual burials and moved to a storage room. The first selection of burials was carried out by one of the authors (Tanasi) to represent the different types of burial and artifact assemblages. Long bones were preferred,

femur and tibia, but it was impossible during the collection to ascertain each bone sampled. For one individual we could collect three molars, but again specific information was impossible to record in absence of proper cleaning and preparation of the bones for anthropological analyses. Many skeletons still preserved their original form, having been removed from the ground while still covered in large amounts of soil. This allowed a relatively easy selection of bone material and teeth, which were not mixed among bodies or in subsequent handling. A scalpel and manual saw were used by two authors (Vianello & Tykot) to obtain enough material for the isotopic analyses. It became evident early on that the state of preservation of some bones was less than optimal due to the type of soil and antiquity, and this was counteracted by sampling larger amounts of bone and by selecting the best-preserved bones. The preparation of samples and the analyses were carried out in the Laboratory for Archaeological Science in the Department of Anthropology, University of South Florida. Collagen from bones and apatite from both bones and teeth was extracted using known and established practices (Ambrose 1990; Koch, Tuross & Fogel 1997; Tykot 2004, 2014).

To extract bone collagen, part of the samples were soaked with a NaOH solution and rinsed with distilled water multiple times. The treatment with HCl acid solution took longer than usual for demineralization, and in a few cases, a second batch from the original sample was selected due to the initial study resulting in the acid consuming most of the poorly preserved bone. In practice, it was noted early if the sample size was insufficient by comparing the residue among vials; a few were significantly below average. In all cases, however, a sufficient and comparable amount of material

remained after the final processing procedure. Pairs of 1 mg collagen samples from 15 individuals were analyzed using a Thermo Finnigan Delta Plus XL with input from a Costech elemental analyzer. The precision is ± 0.1 for $\delta^{13}\text{C}$, ± 0.2 for $\delta^{15}\text{N}$, with results reported relative to VPDB and AIR, respectively. Despite the attention to choose the most suitable bones and the slower preparation process that enabled to recognize low amounts of collagen preserved, only 13 samples out of 15 have yielded valid results. Both collagen yields and C:N ratios in collagen were measured, as yields of less than 1% have been found to be too degraded for reliable analysis, and C:N ratios between 2.9 and 3.7 are generally found to indicate good preservation (DeNiro, 1985; Tykot, 2002).

Bone apatite was also obtained from samples larger than 1 gram of bone, scrubbed clean, and then pulverized using a drill and weighed to the standard measure of 10 mg. A 2% bleach solution was allowed to stand for 72 hours, then rinsed in distilled water and centrifuged (4 times), then pre-treated with 1 M acetic acid/sodium acetate buffer solution for 24 hours, and rinsed again 4 times. Tooth samples were cleaned with a brush and slightly abraded to remove surface contaminants. They have been drilled with care to avoid damaged parts of the enamel, about 100 mg of material was then extracted for analysis. The drilling was largely superficial and occurred in multiple parts of the tooth (effectively scraping superficial enamel for the most part) to avoid the destruction of the teeth. One milligram bone apatite and tooth enamel samples were analyzed on a Finnigan MAT 253 isotope ratio mass spectrometer.

Carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$) isotopes were analyzed from collagen, while carbon ($\delta^{13}\text{C}$) and oxygen ($\delta^{18}\text{O}$) isotopes were analyzed from bone apatite and enamel. No faunal remains have been analyzed, which limit the conclusions on the consumption of specific foods. The ratios between carbon and nitrogen isotopes in human bones can be used to reconstruct diet because of the differential responses in isotopic fractionation of carbon during photosynthesis among different plant groups and variations in assimilation and isotopic fractionation of nitrogen.

Plants from temperate regions follow the C3 (Calvin-Benson) pathway, and have $\delta^{13}\text{C}$ values averaging about -26‰ , while grasses native to hot, arid environments follow the C4 (Hatch-Slack) pathway and have $\delta^{13}\text{C}$ values averaging about -12‰ . Bone collagen carbon isotope values are enriched about $+5\text{‰}$ relative to diet, and bone apatite about $+12\text{‰}$, while bone collagen nitrogen isotope values increase each trophic level about $+3\text{‰}$ (Tykot 2014 and references therein). In Europe and the Mediterranean region, domesticated millet (a C4 plant) has been found, and observed in some isotope studies (e.g. Killgrove & Tykot 2013),

while marine foods also have a more positive stable carbon isotope value.

4. Results and Discussion

The lack of collagen in a few samples can be attributed to the acidity of the soil, while its action appears more substantial in a few bodies as their burial had them in more direct contact with the soil. The difference might result from the covering of some bodies in tight bandages or linen, effectively introducing a further chemical element in the complex chemistry at the time of decomposition, but this can vary also from ointments used (which are chemicals), treatment of the bodies, soil used to cover the burial, offerings of organic nature spilling into the body, or others. We can only suggest that the chemistry was different for some bones, and this may have something to do with the ritual at the time of deposition. The observed state of preservation of the bones shows a correlation between largely vegetarian diet, absence of grave goods and poor preservation. Differences in diet normally do not affect the preservation of bones, and therefore these technical observations hint to different burial practices within the same necropolis.

Experimental data has indicated that different bone tissues preserve different elements of the diet (Ambrose and Norr 1993; Tieszen and Fagre 1993); collagen is produced by proteins while the carbonate of calcium hydroxyapatite (bone apatite) and tooth enamel is produced from a mixture of proteins, carbohydrates and fats. The bone collagen carbon and nitrogen isotope values (Fig. 10) obtained clearly indicate a mostly C3-based protein diet, and suggest little if any seafood in most of the individuals (Tab. 3).

The bone apatite carbon isotope values, however, are more positive than a pure C3-based plant diet. The differences between bone collagen and apatite in the carbon isotopes) are generally consistent, with a

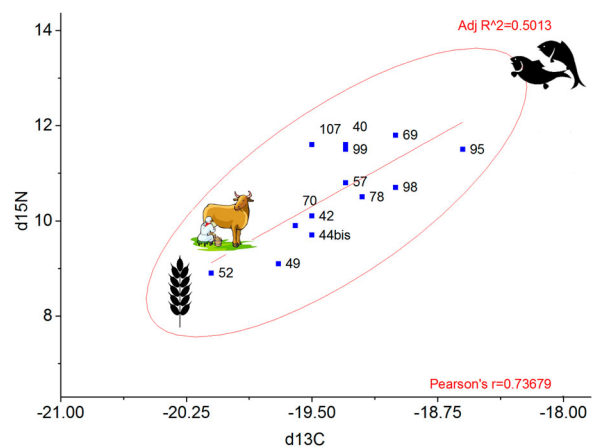


Figure 10. Plot of bone collagen isotopes $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ with generic indicators of C3 plants, terrestrial animals and marine food.

Table 3. Stable isotope data for bone collagen and bone apatite. Oxygen data were also obtained and are included for reference only: they are not sufficient for a discussion of mobility and not relevant for the present discussion on diet, but could be useful to integrate in future studies.

Tomb	USF # co	$\delta^{13}\text{C}$	$\delta^{15}\text{N}$	C:N	USF # ap	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$
28	27795	no collagen yield			27810	-13.9	-2.5
40	27796	-19.3	11.6	3.2	27811	-11.7	-2.9
42	27797	-19.5	10.1	3.3	27812	-11.1	-3.4
44bis	27798	-19.5	9.7	3.3	27813	-10.3	-3.1
49	27799	-19.7	9.1	3.3	27814	-10.9	-3.2
52	27800	-20.1	8.9	3.3	27815	-10.9	-3.1
54	27801	no collagen yield			27816	-11.2	-2.7
57	27802	-19.3	10.8	3.4	27817	-11.2	-3.5
69	27803	-19.0	11.8	3.3	27818	-11.7	-2.7
70	27804	-19.6	9.9	3.4	27819	-11.6	-2.3
78	27805	-19.2	10.5	3.4	27820	-11.3	-3.0
95	27806	-18.6	11.5	3.3	27821	-10.6	-2.9
98	27807	-19.0	10.7	3.4	27822	-10.9	-3.4
99	27808	-19.3	11.5	3.4	27823	-11.6	-2.9
107	27809	-19.5	11.6	3.3	27824	-10.8	-2.9

median difference of -8.1% , greater than the difference expected for consumers of terrestrial foods based on C3 plants. This larger difference supports the direct consumption of plant food with a more positive carbon isotope value than those plants more represented in dietary protein (e.g. through consumption of animal meat and secondary products). This could be either a C4 plant such as millet, and/or a marine plant such as seaweed, both with low nitrogen isotope values. There are greater variances in individuals 44bis and 52 (-9.2%), which are the individuals with the largest intake of plants and no or few grave goods, suggesting that these individuals obtained a more varied diet than collagen alone suggests, albeit still poor in proteins. To this group can be added also individual 49 (-8.8%). On the other side of the scale, individual no. 69 is different in having relatively more negative values in apatite than in collagen, with a difference set at -7.3% . This individual can be divided from those labelled 95 and 98, which together would form the group with the most varied diet, probably based on consumption of some marine food. For individual no. 107 (Tab. 4) the values suggest a reduced range of food during childhood and probably a difference in location between childhood and adulthood, which cannot be confirmed with so few data, but some difference in diet between children and adults would be quite possible in Greek Syracuse.

Fish consumption as resulting from $\delta^{15}\text{N}$ values cannot be recognized across the sample, and even without analyses of local fish, the values appear sufficiently low to deny a similarity in diet with individuals that ate

Table 4. Stable isotope data for tooth enamel.

Tomb/tooth	USF # en	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$
107 M1	27825	-13.1	-3.5
107 M2	27826	-11.0	-2.5
107 M3	27827	-12.4	-3.8

fish regularly in the Greek world. Only the individual in tomb 95 (Fig. 9) may have eaten fish more regularly. The range of values suggest a variability in diet denying the consumption of fish as a staple food.

5. Conclusions

The stable isotope values have been obtained using standardized practices rigorously, with great care to sample a varied set of individuals, and extract collagen, apatite and enamel from all individuals minimizing issues due to the preservation of bones in the soil. The sample is very small, due to funding limitations for a preliminary (pilot) project. The absence of any anthropological analyses, including any cleaning of the bones, is highly problematic. The system of preservation has facilitated the selection of the most useful bones for these analyses (something not always possible due to objections from biological anthropologists using long bones for a variety of anthropological measurements) reducing the impact from poor preservation, but we could not reliably recognize much beyond that we were sampling a femur. We are aware of techniques to counteract the poor preservation of the bones (e.g. Jørkov, Heinemeier & Lynnerup 2007; Sealy, Johnson, Richards & Nehlich 2014) but we found them unnecessary in our pilot study because we could sample plenty of tissue in the best spots, but more refined techniques should be planned for future studies. Values from bone collagen have proven to be the most useful. However, apatite values add to the complexity of the assemblage, and enamel as well as oxygen values at the very least suggest that the preservation is sufficient even for more complex studies than diet reconstruction. From our study, it is possible to recognize a complex and nuanced society, with individuals consuming a varied diet, ranging from poor to rich in animal proteins.

The period in question, Archaic, is the very beginning of the Classical period, and therefore we did not notice the same high nutritional values observed in Athens in that period, but we cannot exclude it for later moments. Our rough suggestion of “wealthy” and “poor” individuals has proven useful, proving a high variability in diet and suggesting possible differences on the basis of social status. This study supports the hypothesis that social stratification may have affected the diet of individuals already in the Archaic period even if a single cemetery was used for all people and differences in graves sizes and grave goods are inconclusive to determine social status and hierarchy. Dietary information is prominent in new analyses of the population in Greek times (Taylor 2017, see especially pp. 131-133; 198-200), and the main approach has been differentiating between genders and recognizing wealthy or elite individuals. None of our samples have yielded values compatible with

malnourishment, despite the total absence of any grave goods in a few burials, and this is consistent with other studies of this period. The results are variable, but without any extreme values, suggesting that social differentiation was still in progress during the Archaic period.

The present study of individuals from Syracuse shows a basic diet that can be described as based on consumption mainly of C3 plants, with a noticeable amount of plants such as millet and/or seaweed, and a few individuals integrating their diet with animal proteins in varying degrees. Marine fish consumption is present at a small scale, as in other Classical poleis that are near the sea or larger rivers, but is not evenly distributed as in Apollonia. Overall, Syracuse appears to have yielded the most dynamic set of samples among those considered here, with marked differences despite all individuals sharing the same cemetery.

Notes on contributors

Davide Tanasi (PhD) is an Assistant Professor with the Department of History at the Center for Virtualization and Applied Spatial Technologies (CVAST) of University of South Florida. He is an archaeologist specializing in Mediterranean prehistory. His research interests include Bronze Age Sicily and Malta, archaeometry of ancient ceramics and glass, computer graphics in archaeology, and digital communication of cultural heritage. He has authored several monographs and a hundred scientific papers in these fields. Since 2013 he has been session editor for archaeometry for the international scientific journal *Open Archaeology*.

Robert H. Tykot (PhD) is a Professor in the Department of Anthropology and Director of the Laboratory for Archaeological Science at USF. His research focuses on chemical analyses of skeletal remains to study dietary practices, of lithic and ceramic artifacts to study trade and exchange, as well as other materials. His labwork has no geographic limitations, while his fieldwork is focused on prehistoric Italy. He is Editor-in-Chief of *STAR*, past-president of the Society for Archaeological Science, and was the chair of the 2010 ISA in Tampa, Florida.

Andrea Vianello (Ph.D.) is Shohet Scholar 2017–2018 of the International Catacomb Society and Visiting Research Fellow at the University of South Florida. He has taught and researched at the universities of Oxford and Sheffield in the UK. He conducts elemental analysis on ceramics, obsidian and metals, as well as stable isotopic analyses on human remains. The focus of his research and extensive literary production has been on trade and mobility in the Mediterranean (Aegean to Iberia), human-environment dynamics, diet and material culture. He is the author of volumes on prehistoric exchanges, exotica, and rivers in prehistory, and a member of the scientific board of the 'Journal of Intercultural and Interdisciplinary Archaeology' (JIIA).

Stephan Hassam (MS) is a Presidential Doctoral Fellow at the University of South Florida in the Department of History. He received his M.S. from the University of Wisconsin-Milwaukee, where he wrote his thesis on a collection of Punico-Roman funerary artifacts from Malta. He has worked at various sites in Sicily and Italy. His research interests lie in Greek and Roman material culture, the archaeology of death, ceramic analysis, and museology.

ORCID

Davide Tanasi  <http://orcid.org/0000-0001-9531-427X>
Robert H. Tykot  <http://orcid.org/0000-0002-8154-9331>
Andrea Vianello  <http://orcid.org/0000-0002-2323-6767>

References

- Ambrose, S.H. 1990. "Preparation and Characterization of Bone and Tooth Collagen for Isotopic Analysis." *Journal of Archaeological Science*, 17: 431–451.
- Ambrose, S.H., and L. Norr 1993. "Experimental Evidence for the Relationship of the Carbon Isotope Ratios of Whole Diet and Dietary Protein to those of Bone Collagen and Carbonate." In *Prehistoric Human Bone: Archaeology at the Molecular Level*, edited by J. B. Lambert, and G. Grupe, 1–37. New York: Springer-Verlag
- DeNiro, M.J., 1985. "Postmortem preservation and alteration of in-vivo bone collagen isotope ratios in relation to paleo-dietary reconstruction." In: *Nature*, 317: 806–809.
- Gentili, G. V. 1961. "(Contrada Palazzo) – Tombe greche tra la via per S. Panagia ed il c.d. «Muro di Gelone» in proprietà Gargallo." *Notizie degli Scavi di Antichità*: 405–418.
- Guzzardi, L. 2003. "Syracuse tra VI e V sec. a.C. La necropoli di Viale Santa Panagia." *Chronos*, 18–19: 39–72.
- Henneberg, R., and M. Henneberg 2003. "The Diet of the Metapontine Population as Reconstructed from the Physical Remains." In *Living off the Chora: Diet and Nutrition at Metaponto*. 29–36. Institute for Classical Archaeology.
- Jørkov, M. L. S., J. Heinemeier, and N. Lynnerup (2007) "Evaluating bone collagen extraction methods for stable isotope analysis in dietary studies." In: *Journal of Archaeological Science*, 34(11): 1824–1829.
- Keenleyside, A., H. Schwarcz, and K. Panayotova 2006. "Stable Isotopic Evidence of Diet in a Greek Colonial Population from the Black Sea." *Journal of Archaeological Science*, 33(9): 1205–1215.
- Killgrove, K., and R.H. Tykot. 2013. "Food for Rome: A Stable Isotope Investigation of Diet in the Imperial Period (1st–3rd Centuries AD)." *Journal of Anthropological Archaeology*, 32: 28–38.
- Koch, P.L., N. Tuross, and M.L. Fogel 1997. "The Effects of Sample Treatment and Diagenesis on the Isotopic Integrity of Carbonate in Biogenic Hydroxylapatite." *Journal of Archaeological Science*, 24: 417–429.
- Kolodny, Y., B. Luz, and O. Navon 1983. "Oxygen Isotope Variations in Phosphate of Biogenic Apatites." *Earth and Planetary Science Letters*, 64: 398–404.
- Lagia, A. 2014. "Health Inequalities in the Classical City: A Biocultural Approach to Socioeconomic Differentials in the Polis of Athens during the Classical, Hellenistic and Imperial Roman periods." In *L'apport de la paléanthropologie funéraire aux sciences historiques. Corps, travail et statut social*, edited by Anne-Catherine Gilles, 95–115. Presses Universitaires du Septentrion: Archaïologia.
- Lagia, A. 2015a. "The Potential and Limitations of Bioarchaeological Investigations in Classical Contexts in Greece: An Example from the Polis of Athens." In *Classical Archaeology in Context: Theory and Practice in Excavation in the Greek World*, edited by D.C. Haggis, and C.M. Antonaccio, 149–173. New York: Walter de Gruyter.
- Lagia, A. 2015b. "Diet and the Polis: An Isotopic Study of Diet in Athens and Laurion during the Classical,

- Hellenistic and Imperial Roman Periods.” In *Archaeodiet in the Greek world: Dietary Reconstruction from Stable Isotope Analysis*, Hesperia Sup, edited by A. Papathanasiou, M.P. Richards, and S.C. Fox, 49: 119–145.
- Lagia, A., A. Papathanasiou, and S. Triantaphyllou 2014. “The State of Approaches to Archaeological Human Remains in Greece.” In *Archaeological Human Remains*, edited by O’Donnabhain, B., and M.C. Lozada, 105–126. New York: Springer.
- Lambrugo, C. 2005. “Per la storia di un mondo “minore”. Alabastra e aryballoi corinzi nella necropoli arcaica di Gela: esegesi di un indicatore infantile.” *Orizzonti* VI, pp. 81–93.
- Orsi, P. 1925. “Nuova necropoli greca dei sec. VII–VII”, *Notizie degli Scavi di Antichità*: 176–321.
- Papathanasiou, A., and S.C. Fox 2015. “Introduction.” In *Archaeodiet in the Greek world: Dietary Reconstruction from Stable Isotope Analysis*, Hesperia Sup, edited by A. Papathanasiou, M.P. Richards, and S.C. Fox, 49: 1–13.
- Pelagatti, P., and G. Voza 1979. “Le necropoli In: Storia della Sicilia, A.A.V.V. Napoli: Società editrice storia di Napoli e della Sicilia.” pp. 357–388,
- Reitsema, L. J. 2013. “Beyond diet reconstruction: Stable isotope applications to human physiology, health, and nutrition.” In: *American Journal of Human Biology*, 25: 445–456.
- Schoeninger, M.J. 2011. “Diet reconstruction and ecology using stable isotope ratios.” In *A companion to biological anthropology*, edited by Larsen, CS, Chichester: Wiley-Blackwell.
- Sealy, J., M. Johnson, M. Richards, and O. Nehlich (2014) “Comparison of two methods of extracting bone collagen for stable carbon and nitrogen isotope analysis: comparing whole bone demineralization with gelatinization and ultrafiltration.” In: *Journal of Archaeological Science*, 47: 64–69.
- Tanasi, D., R. Lanteri, and S. Hassam 2016. “New Data on the Funerary Religion of the Greeks of Sicily: the Archaic Necropolis of Viale Scala Greca at Syracuse.” In *Philosopher Kings and Tragic Heroes. Essays on the Imaged and Ideas from Western Greece*, edited by H. Reid, and D. Tanasi, 329–352. Sioux City: Parnassos Press.
- Taylor, C. 2017. *Poverty, Wealth, and Well-Being: Experiencing Penia in Democratic Athens*. Oxford: Oxford University Press.
- Tieszen, L., and T. Fagre 1993. “Effect of Diet Quality and Composition on the Isotopic Composition of Respiratory CO₂, Bone Collagen, Bone Apatite, and Soft Tissues.” In *Prehistoric Human Bone: Archaeology at the Molecular Level*, edited by J. B. Lambert, G. Grupe, 121–155.
- Tykot, R.H., 2002. “Contribution of stable isotope analysis to understanding dietary variation among the Maya.” In *Archaeological Chemistry: Materials, edited by Jakes, K.A., 214–230. Methods, and Meanings. American Chemical Society, Washington, DC.*
- Tykot, R.H. 2004. “Stable Isotopes and Diet: You Are What You Eat.” In *Physics Methods in Archaeometry. Proceedings of the International School of Physics “Enrico Fermi”, Course CLIV*, edited by M. Martini, M. Milazzo, and M. Piacentini, 433–444. Bologna: Società Italiana di Fisica.
- Tykot, R.H. 2014. “Bone Chemistry and Ancient Diet.” In *Encyclopedia of Global Archaeology*, edited by C. Smith, 931–941. New York: Springer.
- Vika, E. 2011. “Diachronic Dietary Reconstructions in Ancient Thebes, Greece: Results from Stable Isotope Analyses.” *Journal of Archaeological Science*, 38(5): 1157–1163.
- Vika, E., V. Aravantinos, and M. P. Richards 2015. “Aristophanes and Stable Isotopes: a Taste for Freshwater Fish in Classical Thebes (Greece)?” *Antiquity*, 83(322): 1076–1083.
- Vika, E., and T. Theodoropoulou 2012. “Re-investigating Fish Consumption in Greek Antiquity: Results from $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ Analysis from Fish Bone Collagen.” *Journal of Archaeological Science*, 39(5): 1618–1627.
- Whitley, J. 2002. “Objects with Attitude: Biographical Facts and Fallacies in the Study of Late Bronze Age and Early Iron Age Warrior Graves.” *Cambridge Archaeological Journal* 12.2, pp. 217–232.