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RESEARCH ARTICLE

# In service to the sultan: Biological affinity analysis of Vlach Ottoman vassals from the Šarić Struga and Koprivno-Križ sites in southern Croatia

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## Abstract

As a cultural isolate and historically labeled ethnicity, the extent of biological divergence between Vlachs and non-Vlachs in Southeast Europe is not well understood. Here, we present a comparison of metric and non-metric cranial morphology designed to investigate the degree to which a Vlach sample ($n = 32$) from the Ottoman period in southern Croatia is biologically differentiated from non-Vlach communities. By calculating Relethford–Blangero distances using cranial measurements and conducting a mean measure of divergence test based on cranial non-metric traits, we investigated morphological relationships between the Vlach sample and other regional samples. Results from both metric and non-metric analyses indicate a close biological relationship with the non-Vlach community who lived nearby. Lacking substantial differences from the local non-Vlach community, the Vlach ethnicity may have been distinct based on socioeconomic rather than biological factors. This research points to an ethnogenesis more cultural than biological for this historical context.

KEYWORDS

biodistance, craniometrics, Croatia, ethnicity, non-metrics, Ottoman, population history, Vlach

## 1 | INTRODUCTION

Archeology has a long history of searching for new ways to study different forms of human identity in the past. Ethnicity, a particularly complex form of human identity, has been acknowledged as especially difficult to disentangle in archeological contexts (Emberling, 1997; Jones, 1997; Lucy, 2005). With methods and theory from both biological anthropology and archeology, bioarcheology has developed novel ways to analyze identity and ethnicity from people's biological remains (summarized by Knudson & Stojanowski, 2008). In this research, we explore markers of biological identity from archeological skeletal remains associated with a Vlach community in southern Croatia and consider their role in the maintenance of an identity. As the Vlach identity is often labeled an ethnicity, this is a useful case study to evaluate biological versus cultural components of ethnic identity.

While it has been established that ethnicity does not require a genetic component to tie a community together (Cohen, 1974; Comaroff & Comaroff, 2009; Mitchell, 1970; Okamura, 1981; Van Velsen, 1967), biological relationship is nevertheless an important consideration. In some cases of ethnic affiliation, biology or common descent is the factor used to delineate group boundaries. Other times *perceived* common ancestry is employed, and sameness propagated regardless of whether it is matched with actual biological relatedness. By looking at the biological features of a Vlach population from the Ottoman period in Southeast Europe, this research aims to understand the biological character of this group, defined historically as a discrete ethnicity.

  

Utilizing bioarcheological methods designed to quantify biological affinity from human skeletal remains ("biodistance" methods), this research explored potential biological differences between the Vlach population of study and other regional samples. This community was recorded in history as a culturally distinct ethnicity, isolated from others in the region. This isolation was intensified due to collaborations between the Vlachs and the Ottoman administration ruling Croatian lands at the time (Kursar, 2013). Whether this isolation is supported by an actual biological division, however, is unclear. This research contributes bioarcheological methodology for the first time to long-standing debates regarding ethnicity and identity between Vlachs and others in southeast Europe. The evaluation of even one Vlach community carves out a role for bioarcheology in a debate previously dominated by historical evidence.

## 2 | BACKGROUND

### 2.1 | Historical and biological background

The Vlachs (also called Aromuns or Aromanians) are a linguistic and cultural isolate in Europe (Arslan, 2004; Comas et al., 2004). As an identity frequently labeled an ethnicity since the 10th century (Arslan, 2004), the Vlach designation has remained an unsolved piece of Balkan population history for many centuries. The true origins and identity of Vlach communities are a heavily debated historical question. Some historians champion Slavic roots (Kursar, 2013; Radovi Akademije i nauka Bosne i Hercegovine, 1983). Others insist on a pre-Slavic heritage for the Vlachs, insisting they are an indigenous Balkan population present prior to Slavic migrations (Kursar, 2013). Likewise, proposed origins for the Vlachs include Thracian (an Indo-European ethnicity who resided predominately in modern-day Bulgaria), Dacian (another Indo-European community inhabiting modern-day Romania), or Greek (Comas et al., 2004; Schmidt et al., 2001). Adding to this complexity, the term "Vlach" was occasionally used to reference anyone who practiced nomadic and pastoral lifestyles. For example, while Ottoman administration recognized the Vlachs as a separate ethnic group (Arslan, 2004), some records show the term "Vlach" used as a catch-all administrative label for general pastoralists in service to the state. Consequently, smaller pastoral groups were absorbed into this label, grouped by the Ottomans for similar subsistence traditions (Kursar, 2013). This has led some historians to adopt the lower-case "vlach" term to highlight a way of life or profession, rather than an ethnicity (Kursar, 2013).

In part due to their nomadic past, knowledge of the Vlachs and their history remain unclear (Schmidt et al., 2001). Genetic and genealogical research shows divergence between Vlachs and other Balkan populations (Huckenbeck et al., 2001; Scheil et al., 2001; Schmidt et al., 2001). Consequently, research continues to probe questions of origin. Genetic testing was unsuccessful in confirming one of the three commonly proposed biological backgrounds (Thracian, Dacian, or Greek) (Comas et al., 2004). Once again, the idea that Vlachs may be biologically diverse individuals who converged linguistically and culturally was considered. Given this, genetic drift may explain genetic differences between some Vlach communities and other Balkan populations (Bosch et al., 2006; Comas et al., 2004). In some areas, cultural isolation may have given rise to small population groups who eventually diverged from nearby non-Vlach communities through genetic drift (Bosch et al., 2006). Biological processes (such as genetic drift) and cultural processes (such as way-of-life classifications) may have created distinct population histories for different Vlach communities throughout the Balkan Peninsula. As such, exploring Vlach history in one region may not illuminate Vlach populations elsewhere in Southeast Europe, a fact this research bears in mind.

Throughout medieval and Early Modern Southeast Europe, Vlach populations kept to separate, nomadic communities run by their own legal institutions (Fine, 2006, p. 129). Many practiced Christianity, while others converted to Islam when the Ottomans arrived from Anatolia in the 14th century (Kahl, 2006; Wachtel, 2008). Historical records indicate converted and non-converted Vlach communities served as vassals to the Ottoman government, assisting with newly conquered areas as auxiliary military forces in exchange for special privileges (Kursar, 2013). The Vlachs became a well-known ally in some regions, assisting Ottoman control of European lands (Arslan, 2004, p. 122). As Vassals to the administration, Vlachs held distinct positions in the Ottoman Empire. As such, it would be prudent to consider the circumstantial nature of their ethnic division from the non-Vlach European communities they lived among. In this study, the divergence between non-Vlach and Vlach communities in an Ottoman-controlled territory is examined. The evaluation of biological divisions, while in the past sought after as an answer for *all* Vlach communities, is taken down to a local level. Here, we investigate the ability for circumstantial ethnic divisions fueled by the political status of Vlachs as Ottoman vassals to contribute to the maintenance of ethnic divisions in southern Croatia.

### 2.2 | Theoretical background

This research examines the biological nature of an ethnic division in Ottoman-controlled Croatia. A brief review of theoretical literature relevant to the exploration of ethnic identity allows us to better evaluate the bioarcheological data. In the 20th century, much discourse in the social sciences sought a better understanding of concepts of human identity. Early on, ideas of identity and the solidarity people felt within an identity were described as essential, preexisting realities. In the 1950s sociologist Edward Shils coined the term "primordialism," ascribing the strength of human attachments to identity (particularly ethnic identity) not through human interactions but to the tie of blood (Shils, 1957). Later, a contrary position developed, and "circumstantialists" advanced interpretations of identity and ethnic relations as rising out of situations or circumstances (Glazer & Moynihan, 1963; Patterson, 1975; Spicer, 1971). Likewise, circumstantial views stressed the introduction of an opposition as a force that developed strong ethnic ties (Spicer, 1971). While primordialists portrayed ethnicity as fixed and unchanging, circumstantialists argued it was fluid and contingent (Cornell & Hartmann, 2007). As primordial ideas of identity filtered into anthropology (Geertz, 1973; van den Berghe, 1978), circumstantialists were also drawn into anthropological approaches as well. The concept of "situational ethnicity," first coined in the 1960s (Paden, 1967), was used by anthropologists to emphasize the importance of social situations for analyzing ethnic identity (Cohen, 1974; Mitchell, 1970; Okamura, 1981; van Velsen, 1967). This dichotomized position between primordial and circumstantial ethnicity defined much 20th century scholarship on the subject.

Bioarcheology adds evidence to evaluate ethnic identity, past and present. Human identity often has biological as well as cultural components, and interpretations of the human body from archeological contexts can review aspects of identity from both categories. With physical human remains informative and symbolic of individual and group identities, much research on ethnicity, age, gender, and religious identity has been published (Buzon, 2006; Gowland, 2006; Sofaer, 2006; Stodder & Palkovich, 2012; Stone & Walrath, 2006; Wrobel et al., 2017; Zakrzewski, 2011). In this research, bioarcheological data were used to provide a way to question primordial aspects of divergence (biological differences). The presence or absence of distinct biological divergence between Vlach and non-Vlach communities in this context can evaluate the role of circumstantial factors, informed by history, that may have driven the maintenance of ethnic diversity in the region.

## 3 | MATERIALS AND METHODS

### 3.1 | Cranial series

While genealogical and genetic methods were used prior to our work to explore questions of Vlach ethnicity, we elected a morphological approach that explores human skeletal variation as evidence of population history. Post-mortem damage to dentition in many samples made dental form, a strong correlate to neutral genetic data (Irish et al., 2020; Rathmann et al., 2017), unavailable. Cranial variation was used instead. The use of metric cranial variation to study history and migration in past human groups rests on the idea that neutral evolutionary forces are predominantly responsible for variation in cranial form. Despite the fact that heritability of cranial variation can differ between populations and in different environments (Harvati & Weaver, 2006; Hubbe et al., 2009; Roseman, 2004; Smith et al., 2007), overall cranial *shape* patterns have shown to be the result of neutral population history (von Cramon-Taubadel, 2014). A statistically significant correlation between genetic and craniometric data has been found in numerous contexts, showing global patterns of craniometric variation to be informative of neutral population history (Harvati & Weaver, 2006; Roseman, 2004; von Cramon-Taubadel, 2014). In addition to craniometric traits, non-metric variation is often employed as a proxy for genetic data as well. While postcranial non-metric variation is affected by functional modification and remodeling, which may obscure the relationship between skeletal variants and genetics (Tyrrell, 2000), in general, the human cranium is more resistant against these forces. Overall, non-metric traits analyzed from archeological contexts have proven effective representations of genetic information (Hanihara et al., 2003; Ricaut et al., 2010; Stojanowski & Schillaci, 2006). Many projects evaluating ethnicity, group identity, and population history use metric and non-metric cranial morphology (Herrera et al., 2014; McIlvaine et al., 2014; Movsesian & Bakholdina, 2017; Stojanowski & Schillaci, 2006; Zakrzewski, 2011).

Craniometric and non-metric data were collected on a sample of adult crania from each series (see below) except for some previously published data (craniometric measurements from Howells' Berg and Zalavár samples). Adult age was established from the fusion of the spheno-occipital synchondrosis, a biological milestone usually complete between 18 and 25 years of age (White et al., 2012). This is a common point at which an individual is labeled an adult by osteological standards (Scheuer & Black, 2000). When the spheno-occipital region was damaged or missing, other indicators of adult age (i.e., fused medial epicondyles of the clavicle) were used.

Two Vlach cemeteries contributed to the skeletal sample used in this research. Both were excavated outside the coastal city of Split in southern Croatia. The Šarić Struga and Koprivno-Križ sites comprise of two burial grounds. Both cemeteries were used by the Vlach population during the Ottoman period, identified using historical and archeological criteria linked to Vlach communities around Croatia. Ninety-seven graves with 147 individuals from Koprivno-Križ were discovered in 2000 in a burial ground associated with a nearby village inhabited by Vlach Ottoman vassals (Novak & Šlaus, 2011). The Village of Koprivno, while first settled in 1371, was abandoned and resettled with a Vlach population during the Ottoman period in the 1500s (Gjurašin, 2001). The nearby necropolis (Koprivno-Križ) was used between the 16th and 18th centuries (Gjurašin, 2005; Novak & Šlaus, 2011) and can be further connected to the Vlach identity through diagnostic artifacts. Many of the burials were marked with gravestones called *stećaks*, a monolithic slab decorated with simple relief ornaments including half-moons, twisted wreaths, and crosses. These *stećaks* are unique medieval gravestones used by Vlachs throughout the Balkan peninsula (Hrabak, 1953, 1956; Milošević & Šućur, 2008a; Wenzel, 1962). Likewise, many of the burials contained Ottoman coins and artifacts characteristic of Vlachs during this period (Gjurašin, 2002).

Due to a limit in the number of complete crania from Koprivno-Križ, remains from a burial site associated with the Šarić Struga village were added to the sample. The Šarić Struga settlement is roughly 100 km from Koprivno-Križ. Burials found around this settlement had graves characteristic of the Vlach population living in the settlement. Many of the graves were marked by stećak tombstones adorned with crescent or twisted wreath designs, as well as similar ornamentation on some of the coffin sides. While the graves were found predominately without grave goods, a coin below the coffins dating between 1400 and 1413 (Milošević & Šućur, 2008b) provides additional support for connection to the late medieval Vlachs. In total, 40 graves here were connected to the 15th–17th century Vlach community (Milošević & Šućur, 2008b; Tomasović, 2008) adding to our sample of complete crania.

The two Vlach sites of Šarić Struga and Koprivno-Križ were analyzed together as a Vlach sample from southern Croatia. Both collections reside at the Anthropological Center of the Croatian Academy of Sciences and Arts in Zagreb. Twenty-four crania came from the Koprivno site, while eight from Šarić Struga were suitable for measurement. In addition to historical and archeological evidence supporting their combination to produce a picture of Vlachs in the region, a MANOVA test found no statistically significant differences in craniometric measurements between Štarić Struga and Koprivno-Kriz (Wilk's Lambda $= 0.003$, $F[30, 1] = 10.746$, $p = 0.238$). There was also no significant difference between the two subgroups in the non-metric data (PERMANOVA; $F[31, 1] = 1.422$, $p = 0.183$ and $\chi^2 [1, 27] = 18.635$, $p = 0.852$). Consequently, the craniometric and non-metric data for Šarić Struga and Koprivno-Križ were combined to produce a Vlach sample of 32 individuals (15 males, 15 females, and 2 of indeterminate sex).

Data from multiple comparative collections were used to explore the biological character of this Vlach community (Table 1). For the craniometric analysis, regional comparative samples were employed: an Early Modern series from Grifenberg (Berg), Austria; a medieval collection from Zalavár, Hungary; a Bosnian medieval collection; and an Anatolian series. Given the mass movement of European and Anatolian individuals during the Ottoman era in Southeast Europe (Wachtel, 2008), individuals from these areas likely affected population demographics in Ottoman territories. In addition to the regional samples, a medieval series (called Dugopolje) was included. This sample was meant to represent the contemporaneous non-Vlach population local to our Vlach sample (Figure 1). The Anatolian and

**TABLE 1** Study samples: M designates samples used in metric study; NM designates samples used in non-metric study

| Code | Sample | N | Context | M | NM | Data collection |
|---|---|---|---|---|---|---|
| ANAT | Anatolia | $n = 32$ | Pre-1800s individuals collected from various locations in Turkey and Aleppo, Syria | X | X | KG Allen |
| BERG | Berg, Austria | $n = 30$ | Charnel house from isolated village in Carinthia province of Austria | X | X | KG Allen (NM) WW Howells (M) |
| BOS | Bosnia | $n = 40$ | Medieval graveyard at Mistihalj (~1400–1475 AD); 40 km north of Dubrovnik | X | | KG Allen |
| DUG | Dugopolje | $n = 33$ | 13th–16th century | X | X | KG Allen |
| VLACH | Croatian Vlach | $n = 32$ | Koprivno site (15th–18th C) and Šarić Struga site (15th C) | X | X | KG Allen |
| ZAL | Zalavár | $n = 40$ | Medieval; Zalavár, Hungary | X | X | KG Allen (NM) WW Howells (M) |

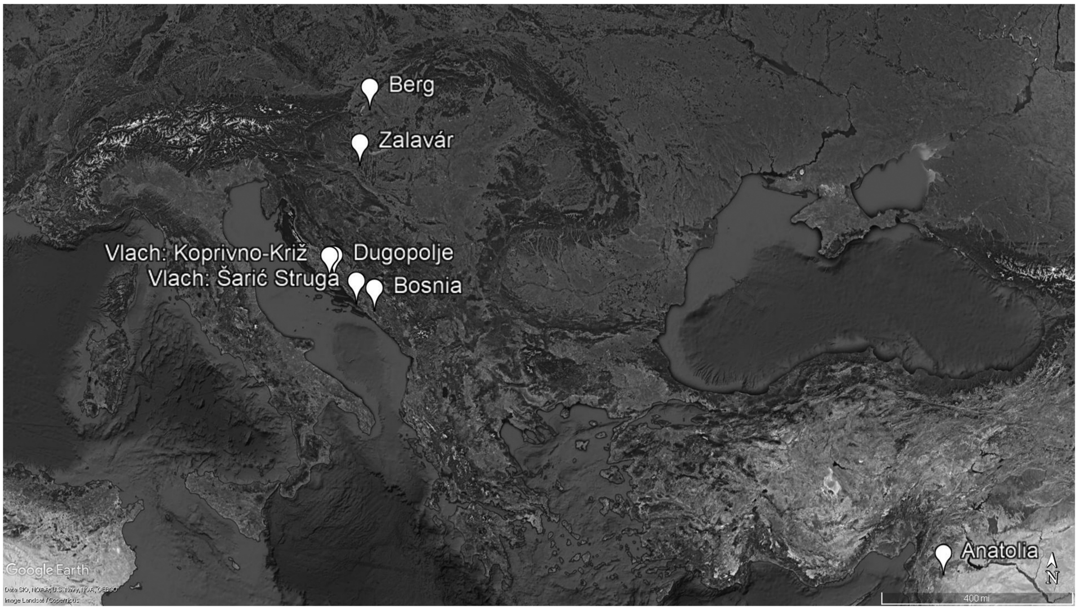


**FIGURE 1** Map from Google Earth Pro (2015). General locations for study sites berg: 47°49′22.73″N 17°2′40.25″E, Zalavár 46°24′2.94″N 16°58′29.01″E, Dugopolje 43°32′45.96″N 16°35′56.95″E, Vlach: Koprivno-Križ 43°31′9.83″N 43°31′9.83″N, Vlach: Šarić Struga 42°58′41.43″N 17°28′40.33″E, Bosnia 42°51′14.82″N 18°7′20.37″E Anatolia 35°51′43.55″N 37°8′47.34″E accessed January 13, 2022

**TABLE 2** Craniometric measurements used (Howells, 1973)

| Measurement | Description | Measurement | Description |
|---|---|---|---|
| GOL | Glabello-occipital length | ZMB | Bimaxillary breadth |
| BNL | Basion-Nasion length | FMB | Bifrontal breadth |
| BBH | Basion-Bregma height | NAS | Nasio-frontal subtense |
| XCB | Maximum cranial breadth | DKB | Interorbital breadth |
| XFB | Maximum frontal breadth | WNB | Simotic chord |
| STB | Bistephanic breadth | IML | Malar length inferior |
| AUB | Biauricular breadth | XML | Malar length maximum |
| WCB | Minimum cranial breadth | WMH | Cheek height |
| ASB | Biasterionic breadth | FOL | Foramen magnum length |
| NLH | Nasal height | FRC | Nasion-Bregma chord |
| OBH | Orbit height left | FRS | Nasion-Bregma subtense |
| OBB | Orbit breadth left | PAC | Bregma-lambda chord |
| JUB | Bijugal breadth | PAS | Bregma-lambda subtense |
| NLB | Nasal breadth | OCC | Lambda-Opisthion chord |
| MDH | Mastoid height | OCS | Lambda-Opisthion subtense |
| MDB | Mastoid width | | |

European samples provide a picture of biological variability throughout the region, while the nearby non-Vlach sample from Dugopolje allowed us to investigate craniometric affinity at a local contemporaneous level. The non-metric dataset came from all samples analyzed metrically, except for the Bosnian group (due to time constraints during data collection). Table 1 summarizes the skeletal collections analyzed with metric and non-metric methods. While available data did not allow us to investigate along the lines of past genetic, genealogical, or historical agendas (e.g., Thracians, Dacians, and Greeks), our samples still provide a robust means of exploring biological affinity in one community, investigating biological differences with another local ethnic group as well as throughout the region.

## 3.2 | Metric data

Our craniometric analysis utilized 31 measurements following Howells' (1973) protocol (Table 2). Measurements for two of the comparative populations (Berg and Zalavár) were previously published by W.W. Howells, while data from the Vlach collection and the other comparative series (Anatolia, Dugopolje, and Bosnia) were collected by the first author (KG Allen). Prior to data collection, an inter-observer exercise was conducted by KG Allen to ensure comparability of measurements between both researchers (Allen & von Cramon-Taubadel, 2017). Missing measurements were estimated using multiple linear regression interpolation by sample in SPSS v. 23. The overall percent of interpolated missing measurements was 2.3%. Once original and interpolated measurements were combined, the dataset was adjusted for isometric scaling variation by dividing each measurement by the geometric mean of all measurements for that individual, creating scale-free shape variables (Falsetti et al., 1993; Jungers et al., 1995).

**TABLE 3** Original list of non-metric traits analyzed (see Hauser & De Stefano, 1989, for full description of these traits)

| | |
|---|---|
| Metopic suture[a] | Inca bone[b] |
| Supraorbital foramina[c] | Trochlear spine[a] |
| Infraorbital suture | Parietal notch bone |
| Multiple infraorbital foramina | Condylar canal[d] |
| Zygomaticofacial foramina | Divided hypoglossal canal[d] |
| Parietal foramina | Foramen ovale incomplete[d] |
| Epipteric bone | Foramen spinosum incomplete |
| Coronal bone | Tympanic dehiscence[d] |
| Sagittal ossicle[d] | Mastoid foramina |
| Apical bone[d] | Double occipital condylar facet[d] |
| Lambdoid ossicle[d] | Jugular foramen bridging external[c] |
| Asterionic bone[d] | Precondylar tubercle[c] |
| Ossicle in occipito-mastoid suture | Palatine torus |

[a]Removed from analysis due to inter-trait correlation concerns.
[b]Removed from analysis due to few or no incidence throughout data.
[c]Removed due to sex-association concerns.
[d]Removed from analysis due to contributory information concerns.

## 3.3 | Non-metric data

Non-metric cranial data came from cranial traits recorded as present or absent following industry standards (Ossenberg, 1969, 2013; Buikstra & Ubelaker, 1994; see Allen, 2017, for more on data collection). All nonmetric data used were collected by the first author of this paper (see Allen, 2017). Initially, 26 traits were considered for this study (Table 3); however, some were removed from final analysis. First, traits with few or no manifestations in the samples were removed. This was the case for one trait that was only recorded twice throughout all samples: the Inca bone. Next, the possibility of inter-trait correlations was evaluated. Occasionally, the occurrence of one non-metric trait can significantly influence the presence or absence of another. Correlated traits share informational content and this redundancy can bias analyses (Harris & Sjøvold, 2004). Because of this, studies often scrutinize problematic trait pairs (Berry & Berry, 1967; Donlon, 2000; Hanihara et al., 2003; Hanihara & Ishida, 2001a, 2001b, 2001c, 2001d; Ricaut et al., 2010; Saunders, 1989). A $\chi^2$ test was used to investigate independence of each non-metric trait pair. Sexes and populations were pooled. Contingency tables provided a $\chi^2$ $p$ value for each pair of traits and $p$ values larger than 0.05 ($p > 0.05$) were investigated, as these may suggest a lack of significant difference between the two traits (Table S3). Some trait-pairs with high $p$ values would be expected by chance alone. We evaluated high $p$ value pairings when both traits were hypostotic (the result of arrested development) or hyperostotic (the result of excess development or ossification). A number of early studies show correlations according to these criteria (Bergman & Hauser, 1985; Hertzog, 1968; Ossenberg, 1969). One trait pair was matching in their hypostotic categorization: metopic suture–trochlear spine. None of the trait pairs with high $\chi^2$ $p$ values were both hyperostotic. Since both the metopic suture and the trochlear spine were also significantly associated with several other traits and shared a similar anatomical region, they were removed from the final analysis. Next, we needed to ensure the remaining traits contain contributory information to the mean measure of divergence (MMD). This was achieved by looking for statistically significant differences between at least one pair of groups being evaluated (Harris & Sjøvold, 2004). This was done using the Fisher's exact test exclusion strategy in AnthropMMD, a choice that implements the strategy recommended by Harris and Sjøvold (2004) to use contributory traits with at least one pair of the groups showing a statistically significant difference (Santos, 2018, 2020). This exclusion strategy removed another 9 traits (Tables 3 and S4). Finally, the remaining traits were evaluated for sex association. Traits strongly correlated with a particular sex can mask among-population relationship patterns by emphasizing patterns of sexual dimorphism instead. A Fisher's exact probability test was used to evaluate variable independence from sex, a common measure for sex-correlation among non-metric variation (Donlon, 2000; Hanihara, 2008; Movsesian & Bakholdina, 2017; Ricaut et al., 2010). The presence and absence of each trait in males and females for all samples were evaluated in PAST version 4.03. A $p$ value of less than 0.05 ($p < 0.05$) was used to indicate a significant correlation. The results show three of the remaining traits had a significant correlation with sex: the supraorbital foramen, jugular foramen bridging external, and the precondylar tubercle (Table S5). We removed these traits. The final list of 11 non-metric traits retained for analysis is presented in Table 4.

**TABLE 4** Final list of non-metric traits retained

| Infraorbital suture | Ossicle in occipito-mastoid suture |
|---|---|
| Multiple infraorbital foramina | Parietal notch bone |
| Zygomaticofacial foramina | Foramen spinosum incomplete |
| Parietal foramina | Mastoid foramen |
| Epipteric bone | Palatine torus |
| Coronal bone | |

## 3.4 | Statistical methods

The final dataset included 31 measurements and 11 non-metric variables. To analyze the craniometric data, the freeware RMET was used to calculate craniometric distance ($D^2$) matrices, following the Relethford-Blangero multivariate extension of the Harpending-Ward model (Harpending & Ward, 1982; Relethford & Blangero, 1990). A $D^2$ matrix was generated expressing the average between-population biological distances among the six cranial series sampled. Among-population differences were then visualized using a Principal Coordinates Analysis (PCoA) in PAST (Hammer et al., 2001). To evaluate biological affinity patterns from the non-metric data, the presence or absence of the 11 non-metric cranial traits was analyzed in a MMD test. Here, the Vlach sample was compared to four other regional populations, as non-metric data were not available for the Bosnian sample. The MMD test was run in R version 4.1.0. using the AnthropMMD package (Santos, 2018). While some studies recommend using an Anscombe formula for transforming trait frequency (Anscombe, 1948), the Freeman–Tukey transformation was employed here (Freeman & Tukey, 1950). This formula is better suited to small sample sizes and traits with frequencies less than 5% or greater than 95% (Green & Suchey, 1976). Significance, as found in values greater than twice their standard deviation (Santos, 2018; Sjøvold, 1973), was calculated by AnthropMMD. The pairwise among-sample MMD values were then visualized using a 2D Multidimensional Scaling (MDS) plot produced in the AnthropMMD package in R.

# 4 | RESULTS

## 4.1 | $D^2$ distance matrix and PCoA

Table 5 displays the $D^2$ matrix from the RMET analysis. The smallest distance between the Vlachs and a comparative sample was with the local non-Vlach Dugopolje community (bolded), followed by the Bosnian sample. The other European populations (Zalavár from Hungary and the Berg from Austria), as well as the Anatolian series displayed higher craniometric distance values.

A PCoA was employed to better visualize the between-group differences presented in the distance matrix shown in Table 5. The result of the PCoA is displayed in Figure 2. This plot should be viewed as a visual representation of between-group variability and biological distance. The eigenvalues of the first two principal coordinates accounted for a vast majority of the overall variation in the dataset (93.97%). Large distances between samples on this plot are indicative of large biological distances. Conversely, samples that plot close to

**TABLE 5** $D^2$ matrix showing between-population craniometric distances

| | BERG | ZALAVÁR | DUGOPOLJE | ANATOLIA | VLACH | BOSNIA |
|---|---|---|---|---|---|---|
| **BERG** | 0 | 0.076986 | 0.193502 | 0.243348 | 0.105427 | 0.167002 |
| **ZALAVÁR** | 0.076986 | 0 | 0.154334 | 0.216309 | 0.116358 | 0.113819 |
| **DUGOPOLJE** | 0.193502 | 0.154334 | 0 | 0.097772 | **0.03927** | 0.053165 |
| **ANATOLIA** | 0.243348 | 0.216309 | 0.097772 | 0 | 0.10984 | 0.185727 |
| **VLACH** | 0.105427 | 0.116358 | 0.039266 | 0.10984 | 0 | 0.078987 |
| **BOSNIA** | 0.167002 | 0.113819 | 0.053165 | 0.185727 | 0.078987 | 0 |

*Note*: Bolded text indicates the smallest distance values for the Vlachs and the comparative samples.

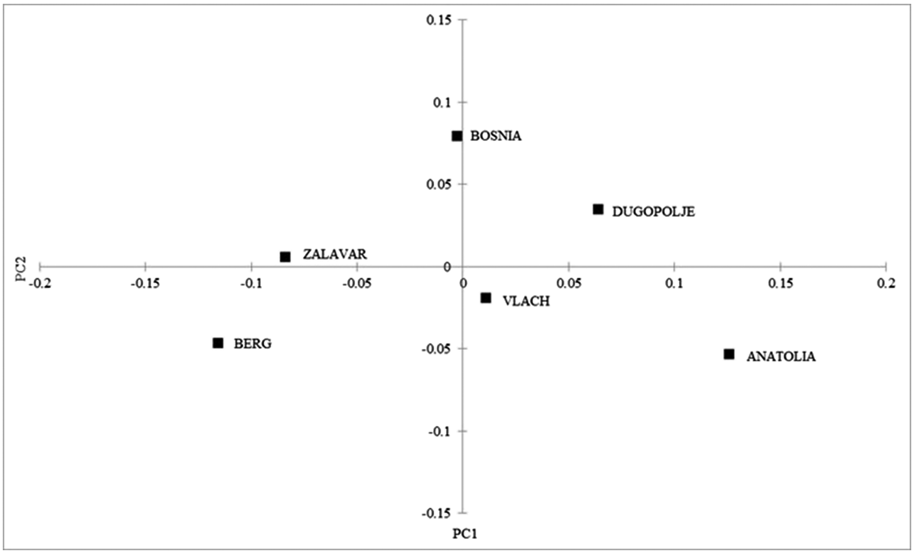


**FIGURE 2** Plot of the first two principal coordinates showing between-group affinity patterns

**TABLE 6** MMD coefficients

| | ANATOLIA | BERG | DUG | VLACH | ZAL |
|---|---|---|---|---|---|
| ANATOLIA | NA | 0.083 | 0.094 | 0.062 | 0.07 |
| BERG | * | NA | 0.122 | 0.093 | 0.251 |
| DUG | * | * | NA | **0.046** | 0.188 |
| VLACH | * | * | **NS** | NA | 0.18 |
| ZAL | * | * | * | * | NA |

*Note*: Higher values represent larger biological differences. Bolded text indicates the smallest distance value between the Vlachs and a comparative sample. Asterisks indicate significant differences between the two samples, while NS highlights a lack of significant difference.

each other indicate lower biological distances. The plot displays the closeness of the Vlach population with the local non-Vlach sample (Dugopolje), as well as the Bosnian collection.

## 4.2 | MMD distance matrix and MDS

Table 6 presents the MMD coefficients based on the analysis of the 11 non-metric cranial traits. As a *dissimilarity* measure, low values indicate similarity between two samples, while higher values imply higher between-sample phenotypic distance (Irish, 2010). Again, the Vlach sample was closest to Dugopolje based on a low MMD coefficient (Table 6). Likewise, Dugopolje was the only sample from which Vlachs did not differ from significantly ("NS"). Figure 3 displays the 2D MDS plot based on the pairwise among-sample MMD values. The associated high Spearman's rho value (0.903) and low stress value of 0.001 indicate that the pairwise MMD dissimilarly matrix was well characterized by the two dimensions of the MDS plot.

# 5 | DISCUSSION

These data show the Vlach sample representing Vlachs living in coastal Croatia during the Ottoman period had little biological divergence from the local non-Vlach community (represented by the Dugopolje sample). In both craniometric and the cranial non-metric tests, the Vlachs show morphological similarity with this local sample. This is not the case with all the regional samples that represent the biological communities influential in the Ottoman era, as the Vlachs differ more from the other European samples as well as from the morphology of Anatolians from the Ottoman's capital region. The distance values for each of these other comparative populations are larger. In the case of the non-metric data, the Vlach have a statistically significant divergence from all other regional samples except Dugopolje. Both lines of morphological evidence show a lack of biological

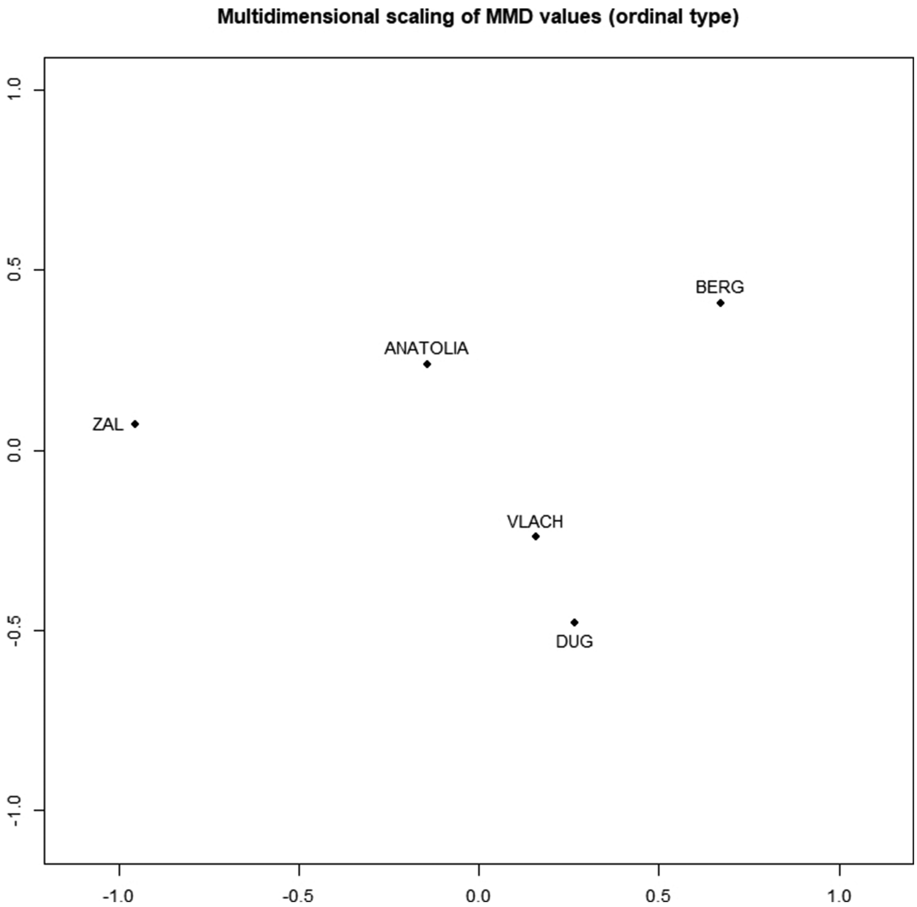


**FIGURE 3** A multidimensional scaling plot (MDS) produced from MMD values. Spearman's rho = 0.903; stress = 0.001

difference between Vlachs and non-Vlachs living together, despite the fact they maintained distinct cultural and ethnic delineations.

This has interesting ramifications for understanding the division maintained historically between Vlach and non-Vlach populations. Labeled as an ethnic group during this time period, the Vlachs were divided from other Southeast Europeans not only in label but also in political affiliation, serving as vassals to the Ottoman military in control of Southeast Europe. Previous research showed how distinctions between Vlachs and nearby non-Vlach communities (such as Dugopolje) translated not only in different ethnic identifiers but differences in health and experience as well (Adamić & Šlaus, 2017; Novak et al., 2007; Šlaus et al., 2018). These social and cultural distinctions appear stronger delineators than biology, however, as indicated by our research. While the ethnic division was an entirely real division, our research indicates a circumstantial divide. This research points to an ethnicity defined by cultural rather than biological differences. This may not be the case with Vlachs in other parts of the region, especially given previous studies where they do diverge biologically from non-Vlach Balkan communities (Huckenbeck et al., 2001; Scheil et al., 2001; Schmidt et al., 2001). Our sample comes from a group of people who maintained Vlach identity, as evident in the use of artifacts and grave markings reserved for Vlachs all around southeast Europe, as well as labels on historical records. Despite connecting with this larger ethnic identity, their ethnogenesis in this particular location does not appear to include the influx of biologically distinct people brought in by the Ottomans, as historical records show happening elsewhere (Kursar, 2013). As such, our results seem to go against previous ideas surrounding the identity of Vlachs in this part of Croatia. Continued research on morphology and other lines of evidence can expand our currently limited understanding of the Vlach identity and the population history of the Balkan peninsula.

## 6 | CONCLUSION

Analyses like these remind us to reconsider the assumption that ethnic divisions always indicate biological ones. While biological factors often play a role in group delineation, ethnic groups can also be defined by non-biological criteria. In this case, it appears the Vlach ethnicity in southern Croatia was defined by an alternative way of life, as herders and eventually Ottoman vassals. These cultural characteristics kept them divided culturally from others in the area. Biological distance analysis as a methodology can be useful in highlighting biological relationships not only between geographically distant communities but also within a small geographic range, highlighting biological divergences or, in our case a *lack* of divergence, as meaningful population characteristics.

While we are limited in our ability to fully understand the biological background of this archeological community in southern Croatia due to limited comparative populations, this research shows the utility in a morphometric approach to unpack this unknown part of European population history. With craniometric and non-metric data from other Balkan populations of potential demographic influence and other Vlach communities, the extent of ethnic heterogeneity, and the way this ethnicity was formed, transformed, and maintained in different historical periods can be sought. Collecting metric and non-metric cranial morphology data are relatively easy and non-destructive, providing evidence that allows us to better explore questions of ethnogenesis, ethnic identity, and population history.

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## CONFLICT OF INTEREST

The authors report no conflicts of interest.

## DATA AVAILABILITY STATEMENT

All data employed here are available from the first author upon reasonable request.

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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