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BETTER TEETH, BETTER HEALTH? THE RELATIONSHIP BETWEEN ENAMEL HYPOPLASIA AND OSTEOLOGICAL STRESS MARKERS IN EBA POPULATION OF NORTHERN SERBIA

ABSTRACT

The Early and Middle Bronze Age Maros culture has been the subject of many archaeological studies aiming to answer questions related to social differentiation, status, and life histories. Archaeological and skeletal material from the necropolises of Mokrin and Ostojićevo has been employed numerous times to answer questions on status, diet, activity and kinship. Even though some things have become clearer, further information on the health status of these Bronze Age populations is needed for a deeper understanding of the social mechanisms and norms of the Maros culture. This paper examines the health status of a Bronze Age population from two archaeological sites, Mokrin and Ostojićevo, using osteological markers of stress and enamel hypoplasia. We hypothesise that individuals who experienced childhood stress, as evidenced by enamel hypoplasia, would exhibit greater vulnerability to infections and disease, as indicated by the presence and frequency of osteological stress markers. The analysis was conducted on a sample of skeletal remains, controlled for age-at-death, and assessed the correlation between enamel hypoplasia and cribra orbitalia, porotic hyperostosis, and periostosis. The findings indicate that reducing the health status to a single osteological stress marker is not a viable approach for this sample size. The analysis of consolidated variables, considering the presence and frequency of any osteological stress markers, yielded more promising results. The frequency of osteological markers showed a statistically significant positive correlation with both the presence and frequency of enamel hypoplasia; so we highlight the importance of considering multiple osteological markers of stress when assessing health status in the past populations.

KEYWORDS: ENAMEL HYPOPLASIA, OSTEOLOGICAL STRESS MARKERS, DOHaD HYPOTHESIS, HEALTH, EARLY BRONZE AGE, MAROS CULTURE.

INTRODUCTION: STRESS AND HEALTH

The term “stress” has gained significant prominence in contemporary medicine, and its usage has become ubiquitous in recent years. Although the concept was initially introduced by Hans Selye in the 1930s in the context of endocrinology (Selye 1936: 32; 1976), it has since evolved to encompass both physiological and psychological aspects in popular discourse, and is commonly used in the field of bioarchaeology (Temple and Goodman 2014; Reitsema and McIlvaine 2014). While criticism of the usage of “stress indicators” in bioarchaeology because of their vagueness is valid (Temple and Goodman 2014; Edinburgh and Rando 2020), with proper contextualisation and specific research questions, they can still be very useful tools. Bioarchaeological stress markers include porotic hyperostosis, *cribra orbitalia*, osteomyelitis, periostosis (Ortner 2003; Walker *et al.* 2009; Klaus 2017; Rivera and Mirazon Lahr 2017; Roberts 2019), skeletal growth (Armelagos *et al*. 1972; Cook 1984; Hoppa 1992) and dental enamel hypoplasia (Goodman and Rose 1990; Hillson 2014) among others. Their commonality lies in their disputed or unknown etiology, as they may not provide a definitive diagnosis, but rather serve as evidence of a physiological stress event experienced by the individual.

The question of the osteological paradox (Wood *et al.* 1992) has influenced both studies of stress indicators in physical anthropology and the analysis of the relationship between morbidity and mortality and the formation of stress indicators. The relationship between longevity and enamel defects has been at least somewhat confirmed in many studies (Armelagos *et al.* 2009; Amoroso, Garcia and Cardoso 2014), but researchers still urge caution because the strength of this correlation varies from context to context. Wood's theory drew attention to the still frequent typologically oriented works and directed future stress research to include as wide a range of factors as possible in their analyses (Klaus 2014; Reitsema and McIlvaine 2014; Temple and Goodman 2014). The field of physical anthropology has begun to integrate methods, theories and approaches of epidemiology (DeWitte 2014; Klaus 2014; Zuckerman 2014; Paskoff and Sattenspiel 2019), medical anthropology (Singer 2015), and evolutionary biology (Kinnally 2014; Amoroso and Garcia 2018) into stress studies in an attempt to move away from a typological and descriptive approach to research. D. Temple and J. Goodman, in their introduction to the special issue of the American Journal of Physical Anthropology devoted to the relationship between stress and health in physical anthropology, appeal to researchers to keep in mind that the relationship between indicators of stress and health is unclear and imperfect, and that its interpretation varies considerably depending on the context of the skeletons being investigated. In addition to careful contextualisation, their proposal is an evolutionary approach to investigating the plasticity of the human response to stress through research in both human biology and primatology (Temple and Goodman 2014: 190).

In contrast to bones, which undergo constant remodelling throughout an individual's life, dental tissues remain unchanged once they are formed, barring external factors such as attrition or caries (Goodman and Rose 1990: 61-63; Hillson 2014: 32). This enduring quality makes teeth a reliable source of information on an individual's health and development during tooth formation, i.e., infancy and childhood. Anthropological analysis commonly utilises dentition to determine an individual's age, to infer indirect data on diet through examination of caries, attrition and calculus (Buikstra and Ubelaker 1994; White and Folkens 2012), to determine whether teeth were used as additional tools (Larsen 1995; Minozzi *et al.* 2003), and to evaluate childhood health by examining tooth enamel defects (Goodman and Armelagos 1988; Goodman 1993; Armelagos *et al.* 2009).

Two properties of dental enamel enable the inference of childhood health data from adults' teeth. Firstly, ameloblasts, the cells responsible for secreting the enamel matrix, are sensitive enough to cease secretion in response to physiological stress induced by illness or poor nutrition, without undergoing permanent damage. Consequently, when the stressor ceases, ameloblasts resume secretion, while the stress episode remains "recorded" in the enamel matrix in the form of a defect. Following the completion of enamel matrix secretion, ameloblasts undergo changes in shape and function and begin the process of enamel matrix calcification, during which the matrix loses proteins and water and becomes inert (Hillson 2014: 32). This inertness of the enamel is the second characteristic of teeth that allows the assessment of childhood health from adult teeth, as any defects in the enamel after calcification remain "sealed" as permanent markers of the stress episode (Goodman and Rose 1990; Hillson 2014).

In this paper we shall try to gain more understanding of the health status of a Bronze Age population from two archaeological sites - Mokrin and Ostojićevo - using osteological markers of stress. These two sites are important necropoles of the Early Bronze Age Maros culture which, owing to the abundance and variety of artifacts, wealth of information due to exceptional documentation and fairly good state of preservation, have been subjects of numerous studies on funerary rituals, social status, activity, kinship and life histories of people in Bronze Age Europe. Health and disease are not just important for the understanding of the life history of an individual, they are inextricably connected with various cultural norms and both horizontal and vertical social status. In that vein, to have a holistic grasp of life in Bronze Age Maros communities we need to understand their health status as well. Our principal hypothesis is the *Developmental Origins of Health and Disease* framework (Barker 2004: 31), which posits that episodes of physiological stress survived in childhood lead to negative health outcomes in later life. We hypothesize that those individuals who have survived episodes of stress in their formative years, as evidenced by dental enamel hypoplasia, may exhibit greater vulnerability to infections and disease, as indicated by more frequent markers of osteological stress, such as porotic hyperostosis, *cribra orbitalia* and periostosis. Furthermore, we will explore whether there are significant differences in health status between men and women in this population.

Figure 1. Map of the Banat region with the Mokrin and Ostojićevo necropolises (done using R project software: R Core Team 2022, ggplot 2 package: Wickham 2016).

MATERIALS

The Early and Middle Bronze Age Maros culture flourished in the Carpathian Basin, encompassing the territories of modern-day Hungary, Romania, and Serbia. Its borders are the rivers Koros in the north, Tisza in the west, and Zlatica and Galacka in the south (Bona 1975: 79; O'Shea 1996: 38). Most sites are grouped around the confluence of the rivers Maros and Tisza (Girić 1971: 231). The Maros culture was formed shortly after the disintegration of large cultural complexes of the Late Copper Age, and it is absolutely dated to a period between 2700 - 1700/1500 BC (Girić 1971; O'Shea 1992; O'Shea *et al.* 2019). Maros sites have been intensively researched and analysed, especially the necropoles, famous for various artifacts and an abundance of metal jewellery and weapons, with multiple sites being subjects of fieldwork in the last decade.

The Mokrin necropolis is situated in the northern Banat region of Serbia (**Figure 1**), in close proximity to the city of Kikinda (Girić 1971: 9). To date, a total of 319 graves have been uncovered, with an estimated 50-100 graves remaining undisturbed (Girić 1971: 34). Initial excavation campaigns were carried out in the 1950s and 1960s, which uncovered most of the graves, while anew excavation campaign started in 2020 and is still ongoing (Pendić *et al.* 2022). Most of the deceased were buried in individual graves, in a crouched position on their side, oriented north-south or south-north, facing towards the east. Grave goods included ceramic vessels, copper and bronze daggers and axes, as well as various types of jewellery made from copper, bronze, gold, seashells, animal teeth, kaolin beads and, in one case, even a human rib (Girić 1971; Stefanović 2006; Ljuština, Krečković and Radišić 2019). The necropolis has been absolutely dated to 2100 - 1800 BC (O'Shea 1992), although recent excavation campaigns have provided evidence of later use of the site, probably dating to the Early Middle Ages[1]. The Mokrin necropolis has been the subject of numerous studies, both archaeological (Girić 1971; O'Shea 1996; Stojanović *et al.* 2020; Pendić *et al.* 2022) and bioarchaeological (Porčić and Stefanović 2009; Stefanović 2008; Stefanović and Porčić 2013; Žegarac *et al.* 2021; Blagojević 2020; Vitezović 2017; Krečković Gavrilović 2022).

[1] Results of the new excavation campaign of the Mokrin necropolis are still not published, but the author of this paper has been a part of the excavation team, so she has a first-hand account of the new found graves.

The Ostojićevo necropolis is situated in the northern Banat region of Serbia (**Figure 1**), in the vicinity of the city of Kikinda. The site is located on the edge of the village of Ostojićevo, on the shore of a now dry meander of the Tisza river (Milašinović 2008: 38). The site was excavated in the 1990s and, unlike Mokrin, it is a multi-layered site. A total of 77 graves belonging to Maros culture come from the oldest layer, while the remaining 208 have been dated to the Middle Bronze Age (Milašinović 2008: 39; O'Shea *et al.* 2019: 617–618), with a clearly demarcated hiatus period between the two. The necropolis has been absolutely dated from c. 2000 BC for the Maros graves, with the hiatus beginning at around 1800 BC, while the necropolis was again put to use around 1600 BC (O'Shea *et al.* 2019: 604–623). Unlike Mokrin, archaeological material from Ostojićevo hasnot been published in its entirety as of yet, although it has been analysed. L. Milašinović (2008) analysed the grave goods for her unpublished Master's thesis, D. Vučetić (2015) examined markers of occupational stress of the Ostojićevo population, and T. Blagojević (2020) published some of the archaeozoological material from the Ostojićevo graves.

METHODS

The aim of this study is to investigate the proposed hypothesis regarding the potential correlation between episodes of physiological stress experienced during childhood and subsequent health outcomes. To achieve this, we will utilize two types of osteological markers of stress, namely dental enamel hypoplasia to assess episodes of childhood stress and *cribra orbitalia*, porotic hyperostosis and periostosis to determine the individual's health status in later life. Although the paleopathological analysis of the skeletal material was more extensive, due to poor preservation of the osteological material, only these three markers were recorded in adequate quantities for statistical analysis.

For this paper, dental enamel hypoplasia was analysed macroscopically and, when necessary, with a hand-held magnifying lens. Given the considerable sample size, which exceeded the feasible capacity for scanning electron microscopy (SEM) analysis within a reasonable time and cost constraints, a macroscopic approach was deemed more practical. We established a specific protocol for the recording of enamel hypoplasia that included observation of tooth presence/absence, presence/absence of hypoplastic defects of enamel, quantification of the total number of defects, measurement of the total height of tooth crown, and determination of the height at which the defects were detected. Teeth were observed under two light sources - natural light and a table top lamp, set up in such a way that light refraction made defects easier to observe on a highly reflective enamel surface. In addition, teeth were cleaned of sediment and glue with the use of brushes, dental probes and an acetone solution as needed.

To calculate when the episode of stress that resulted in a defect occurred, i.e., the age of the individual when enamel hypoplasia formed, we used the height of the crown and height at which the defects were detected. We utilized previously published tooth crown growth schedules to calculate the age-at-formation of the defects (**Table 1**); for incisors, canines and molars we used formation schedules established by D. Reid and M. Dean (2006: 343–344) and for premolars those created by S. Holt and colleagues (Holt, Reid and Guatelli-Steinberg 2012: 6).

Osteological markers of stress were recorded in accordance with standards of physical anthropology (Mann and Hunt 2013; Ortner 2003; Roberts 2019). They were marked as present, absent or bone missing.

Of 312 graves from the old excavations of the Mokrin necropolis, for this paper we have sampled the skeletal remains of 92 individuals. We have only included the remains of adult individuals with appropriate levels of preservation of cranial, postcranial and dental material. The state of preservation of the osseous material is poor to medium due to taphonomic processes, mainly the high acidity of the sediment in which the deceased were interred, as well as the amount of previous handling and analyses of the material.

The state of preservation of the skeletal material from the Ostojićevo necropolis is considerably better, albeit the number of Maros graves available for analysis is comparatively modest. We included the skeletal remains of 36 adult individuals from the 77 Maros graves excavated at Ostojićevo for our investigation.

Decile of crown length *	UI1	UI2	UC	LI1	LI2	LC
1st	1.1-1.3	1.8 - 2.0	1.7 - 1.9	0.8/1.0 - 1.0/1.1	1.0 - 1.1/1.2	1.4/1.5 - 1.6/1.7
2nd	1.3 - 1.5/1.6	2.0 - 2.2	1.9 - 2.1/2.2	1.0/1.1 - 1.1/1.3	1.1/1.2 - 1.3	1.6/1.7 - 1.9/2.0
3rd	1.5/1.6 - 1.7/1.8	2.2 - 2.4	2.1/2.2 - 2.3/2.4	1.1/1.3 - 1.3/1.5	1.3 - 1.5	1.9/2.0 - 2.1/2.3
4th	1.7/1.8 - 1.9/2.0	2.4 - 2.6/2.7	2.3/2.4 - 2.5/2.7	1.3/1.5 - 1.5/1.7	1.5 - 1.7/1.8	2.1/2.3 - 2.4/2.7
5th	1.9/2.0 - 2.2/2.4	2.6/2.7 - 2.9	2.5/2.7 - 2.8/3.0	1.5/1.7 - 1.7/2.0	1.7/1.8 - 1.9/2.1	2.4/2.7 - 2.8/3.1
6th	2.2/2.4 - 2.5/2.9	2.9 - 3.2/3.3	2.8/3.0 - 3.1/3.4	1.7/2.0 - 2.0/2.3	1.9/2.1 - 2.2/2.4	2.8/3.1 - 3.2/3.6
7th	2.5/2.9 - 2.9/3.4	3.2/3.3 - 3.5/3.7	3.1/3.4 - 3.5/3.8	2.0/2.3 - 2.3/2.6	2.2/2.4 - 2.6/2.8	3.2/3.6 - 3.7/4.2
8th	2.9/3.4 - 3.4/3.9	3.5/3.7 - 3.9/4.1	3.5/3.8 - 4.0/4.3	2.3/2.6 - 2.7/3.0	2.6/2.8 - 3.0/3.3	3.7/4.2 - 4.2/4.9
9th	3.4/3.9 - 3.8/4.4	3.9/4.1 - 4.4/4.6	4.0/4.3 - 4.4/4.8	2.7/3.0 - 3.1/3.4	3.0/3.3 - 3.4/3.7	4.2/4.9 - 4.7/5.6
10th	3.8/4.4 - 4.2/5.0	4.4/4.6 - 4.8/5.3	4.4/4.8 - 4.8/5.3	3.1/3.4 - 3.4/3.8	3.4/3.7 - 3.8/4.2	4.7/5.6 - 5.2/6.2

Table 1. Mean estimated chronological age of enamel formation in anterior teeth for each decile of crown length for anterior teeth. Estimates are given for both southern African and north American samples according to Reid and Dean (2006: fig.3). *Deciles of crown length are numbered from apical (1st decile) to CEJ (10th decile)

In addition to the data concerning osteological markers of stress, we collected data on sex and age of the individuals, according to current standards in physical anthropology (Buikstra and Ubelaker 1994; White and Folkens 2012). All the statistical analyses for this paper were done in IBM SPSS Statistics 23 software.

RESULTS

Preservation of the dentition of the individuals buried at Mokrin and Ostojićevo

As was previously mentioned, the state of preservation of the osseous material from Mokrin and Ostojićevo is suboptimal. Although dental remains tend to have better preservation, numerous individuals were excluded from the sample due to having only a limited number of teeth or none at all. In this study, we define preservation as the presence of at least one tooth of each type in a tooth row, regardless of its lateralisation. In other words, mandibular dentition is considered to be 100% preserved when one central incisor, one lateral incisor, one canine, one first premolar, one second premolar, and one first, second, and third molar are present, irrespective of their location within the left or right mandible. As tooth enamel formation is not dependent on lateralisation, but on tooth type (Hillson 2014: 33), having at least one tooth from each pair of the same type is sufficient for unhindered tracking of the tooth formation sequence. Approximately 60% of individuals in our sample had more than a half of their dentition preserved (see **Table 2**).

	<25%	25-49%	50-74%	>75%
Mokrin	12 (13%)	27 (29.3%)	36 (39.1%)	17 (18.5%)
Ostojićevo	3 (9.4%)	8 (25%)	14 (43.8%)	7 (21.9%)
total	15 (12.1%)	35 (28.2%)	50 (40.3%)	24 (19.4%)

Table 2. Preservation of dentition for the sample from Mokrin and Ostojićevo (adapted from Krečković Gavrilović 2022: 68, fig. 5.1).

In this study we employed two variables to monitor the osteological markers of stress: their presence and their frequency. We observed three markers of stress for each individual: *cribra orbitalia*, porotic hyperostosis and periostosis. To mark osteological markers of stress as present, the presence of any of the aforementioned markers was enough; to mark it as absent, the skeleton of the individual had to be preserved enough so we could safely say the absence of the marker wasnot due to poor preservation. The frequency of osteological markers of stress variable follows the same logic regarding the absence of the markers, and uses values 1-3 depending how many of the three markers were found on the skeleton. All skeletons thatwere not preserved enough were excluded from the analysis.

To maximize the sample size for the analysis, the individuals were separated into three broad age categories: the youngest adults in the sample (18-35), middle-aged group (35-50), and the oldest individuals in the sample (50+). However, due to the poor preservation of the skeletal material, the age ranges for most individuals were very broad, rendering this classification rudimentary and imperfect.

Following the logic of the osteological paradox approach, older individuals, having lived longer lives, could have had more opportunities to develop markers of stress on their skeletons (Wood *et al.* 1992: 352). To establish if there is a relationship between the presence of osteological markers of stress and age at death, we conducted a correlation test using Kendall's tau coefficient. Our findings revealed a weak positive correlation between the presence of osteological markers of stress and the age at death. However, this correlation was not statistically significant (Kendall's tau=0.33; p=0.123; N=87). Additionally, a correlation test using Kendall's tau coefficient showed a very weak positive correlation between the frequency of osteological markers of stress and the age at death. Nevertheless, this correlation was also not statistically significant (Kendall's tau= 0.117; p=0.295; N=68). As our results indicated that age at death was not associated with either the presence or frequency of the observed osteological stress markers, we proceeded to examine the correlation between these markers and enamel hypoplasia.

Childhood stress and the presence of cribra orbitalia

To ascertain if there is a relationship between an episode of physiological stress survived in childhood signalled by enamel hypoplasia and formation of *cribra orbitalia,* we conducted a correlation test using Kendall's tau coefficient (**Figure 2**). The results showed that there is a very weak positive correlation between the presence of *cribra orbitalia* and enamel hypoplasia that is not statistically significant (Kendall's tau=0.078; p=.434; N=101). The same was true for the sample divided by sex,as both men (Kendall's tau=0.124; p=.375; N=45) and women (Kendall's tau=0.006; p=.967; N=49) demonstrated a similarly weak positive correlation that was not statistically significant.

By utilizing the tables of estimated timing of enamel formation (Reid and Dean 2006; Holt, Reid and Guatelli-Steinberg 2012), it is possible to infer the number of physiological stress events experienced by an individual during childhood while their teeth were developing. Enamel formation timelines were used to divide the developmental period into five distinct phases for the purposes of this paper, namely: 0.8-2.4 years, 2.5-3.4 years, 3.5-4.4 years, 4.5-5.4 years, and 5.5-6.4 years. These phases were employed to ascertain the frequency of childhood stress episodes that an individual may have experienced and survived.

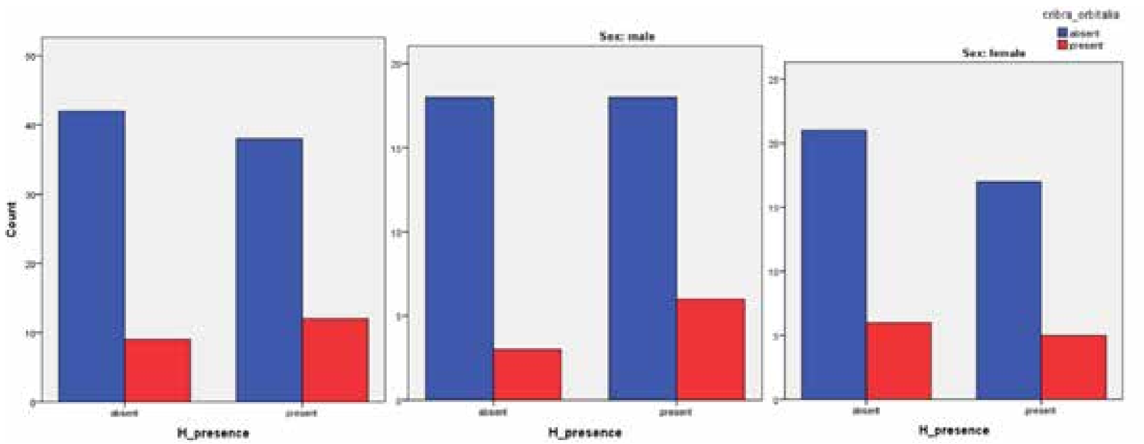

Figure 2. The presence of *cribra orbitalia* compared to the presence of enamel hypoplasia. Bar graphs to the left represent the whole sample, the middle ones are for the male and the far right are for the female sample (done using IBM SPSS Software).

Despite the lack of a statistically significant correlation between the presence of enamel hypoplasia and *cribra orbitalia*, an investigation was conducted to examine the potential correlation between the frequency of stress episodes indicated by enamel hypoplasia and the frequency of *cribra orbitalia*, utilizing Kendall's tau coefficient (**Figure 2**). The analysis was conducted on the entire sample and yielded a very weak positive correlation that was not statistically significant (Kendall's tau=0.076; p=.424; N=102). A similar outcome was observed for the male sample, which showed a weak positive correlation that was not statistically significant (Kendall's tau=0.132; p=.357; N=45). On the other hand, the female sample displayed a very weak negative correlation, which was also not statistically significant (Kendall's tau=-0.007; p=.959; N=50).

Childhood stress and porotic hyperostosis

In our analysis of the Mokrin and Ostojićevo samples, we noted a considerably lower incidence of porotic hyperostosis relative to *cribra orbitalia*. We again tested the correlation between the presence of enamel hypoplasia and porotic hyperostosis using Kendall's tau coefficient (**Figure 3**). The results showed a statistically significant positive correlation between the two variables (Kendall's tau= 0.258; p=.007; N=112). When we separated the sample by sex, a very weak positive correlation was observed for the male sample, which was not statistically significant (Kendall's tau=0.231; p=.110; N=49). Conversely, a statistically significant positive correlation was detected for the female sample, with a Kendall's tau coefficient of 0.307 and a p-value of .024, based on a sample of 55 individuals.

In addition, we tested the correlation between the presence of porotic hyperostosis and the frequency of enamel hypoplasia using Kendall's tau coefficient (**Figure 3**). The results revealed a statistically significant weak positive correlation for the entire sample (Kendall's tau=0.215; p=.017; N=113). When we separated the sample by sex, a statistically significant weak positive correlation was found for the male sample (Kendall's tau=0.296; p=.031; N=49), whereas for the female sample a weak positive correlation was observed, which was not statistically significant (Kendall's tau=0.185; p=.149; N=56).

Childhood stress and periostosis

Due to the subpar preservation of the skeletal material, the sample size for periostosis was the smallest one. Our analysis using Kendall's tau coefficient (**Figure 4**) revealed a very weak positive correlation between the presence of periostosis and enamel hypoplasia that was not statistically significant (Kendall's tau=0.047; p=.667; N=86). For the male sample we found a weak negative correlation between periostosis and enamel hypoplasia that was not statistically significant (Kendall's tau=-0.108; p=.506; N=39). Conversely, for the female sample, the correlation test showed a

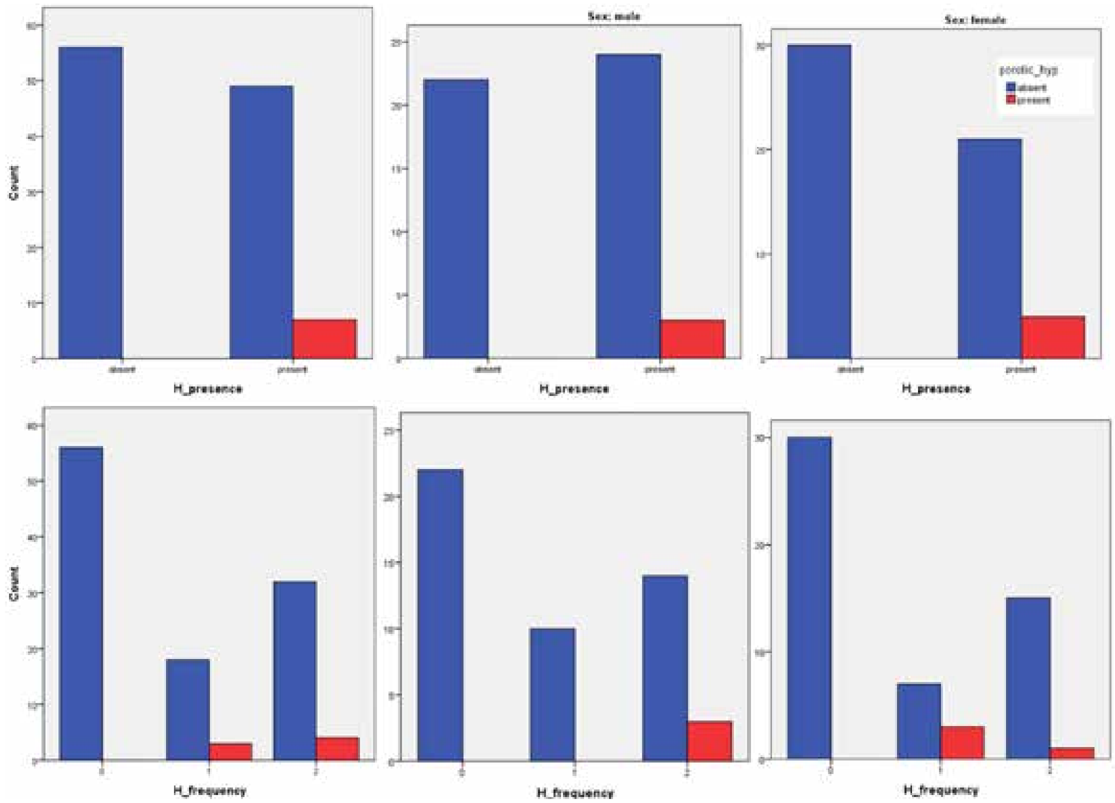

Figure 3. The presence of porotic hyperostosis compared to the presence (upper row) and frequency of enamel hypoplasia. Bar graphs to the left represent the whole sample, the middle ones are for the male and the far right are for the female sample (done using IBM SPSS Software).

weak positive correlation between the presence of periostosis and enamel hypoplasia that was not statistically significant (Kendall's tau=0.100; p=.528; N=41).

We further examined the association between periostosis and enamel hypoplasia frequency using Kendall's tau correlation coefficient (**Figure 4**). Our analysis revealed no statistically significant correlation between the two variables (Kendall's tau = 0.0001, p = .988, N = 87). When we divided the sample by sex, the male sample displayed a weak negative correlation between periostosis and the frequency of enamel hypoplasia, which was not statistically significant (Kendall's tau=-0.119; p=.440; N=39). On the other hand, for the female sample no statistically significant correlation was observed (Kendall's tau=0.000; p=1.000; N=42).

Combined stress markers presence variable

To enhance the statistical power of our study, we combined the data on *cribra orbitalia*, porotic hyperostosis, and periostosis into a single variable of "presence of osteological markers of stress". This approach allowed us to increase the sample size, albeit with somewhat simplified paleopathological information. We employed Kendall's tau correlation coefficient to examine the correlation between the combined variable and enamel hypoplasia frequency (**Figure 5**).

When tested for a correlation between the presence of enamel hypoplasia and the presence of osteological markers of stress, the results showed a weak positive correlation that was not statistically significant (Kendall's tau=0.151; p=.122; N=106). Subsequently, when we separated the sample by sex, the results for men showed a very weak negative correlation that was not statistically significant (Kendall-s tau=-0.023; p=.883; N=42). For women however, a weak positive correlation was present, but again, it was not statistically significant (Kendall's tau=0.180; p=.178; N=49).

The presence of osteological markers of stress was correlated with the frequency of enamel hypoplasia as well, using Kendall's tau correlation

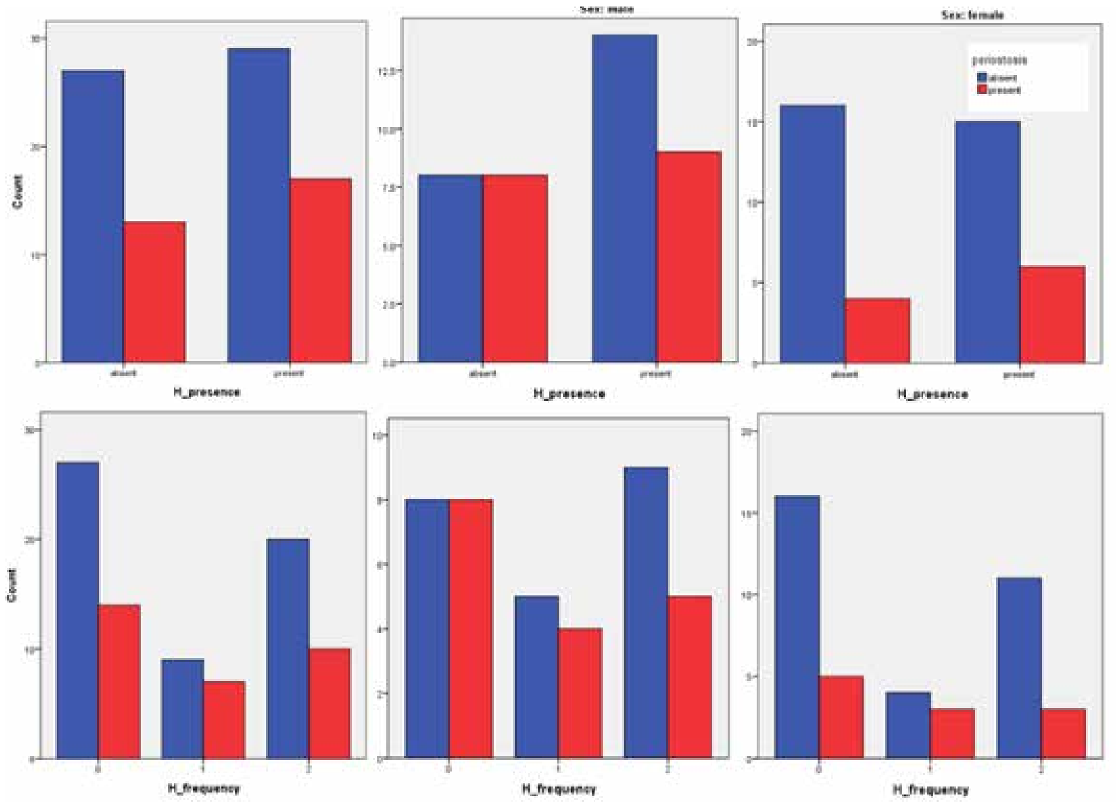

Figure 4. The presence of periostosis compared to the presence (upper row) and frequency of enamel hypoplasia. Bar graphs to the left represent the whole sample, the middle ones are for the male and the far right are for the female sample (done using IBM SPSS Software).

coefficient (**Figure 5**). The results revealed a statistically significant weak positive correlation between the two (Kendall's tau=0.310; p=.011; N=68). When the sample was divided by sex, the correlation analysis for men showed a weak correlation that was marginally statistically significant (Kendall's tau=0.328; p=.061; N=31). Similarly, for women, the results indicated a weak correlation, but which was not statistically significant (Kendall's tau=0.246; p=.154; N=33).

Combined stress markers frequency variable

To further investigate the osteological markers of stress, we analysed their frequency, creating a variable that combines all data on the frequency of osteological stress markers. We created a 1-3 scale depending on the number of osteological stress markers recorded on an individual. Skeletons that were not sufficiently preserved for the observation of any of the stress markers were excluded from the sample. We then tested for a correlation between this variable and the presence of enamel hypoplasia Kendall's tau coefficient (**Figure 6**). The results showed that there was a positive correlation that was statistically significant (Kendall's tau=0.302; p=.011; N=68). When we separated the sample by sex, the results for men showed a positive correlation that was marginally statistically significant (Kendall's tau=0.328; p=.061; N=31). For women the results showed a weak positive correlation that was not statistically significant (Kendall's tau= 0.246; p=.154; N=33).

We also examined the correlation between the frequency of osteological markers of stress and the frequency of enamel hypoplasia using Kendall's tau correlation coefficient (**Figure 6**). The results indicated a marginally significant weak positive correlation (Kendall's tau=0.206; p=.065; N=69). After dividing the sample by sex, the results for men showed a marginally significant weak positive correlation (Kendall's tau=0.310; p=.061; N=31). However, for women, the very weak positive correlation was not statistically significant (Kendall's tau=0.072; p=.665; N=34).

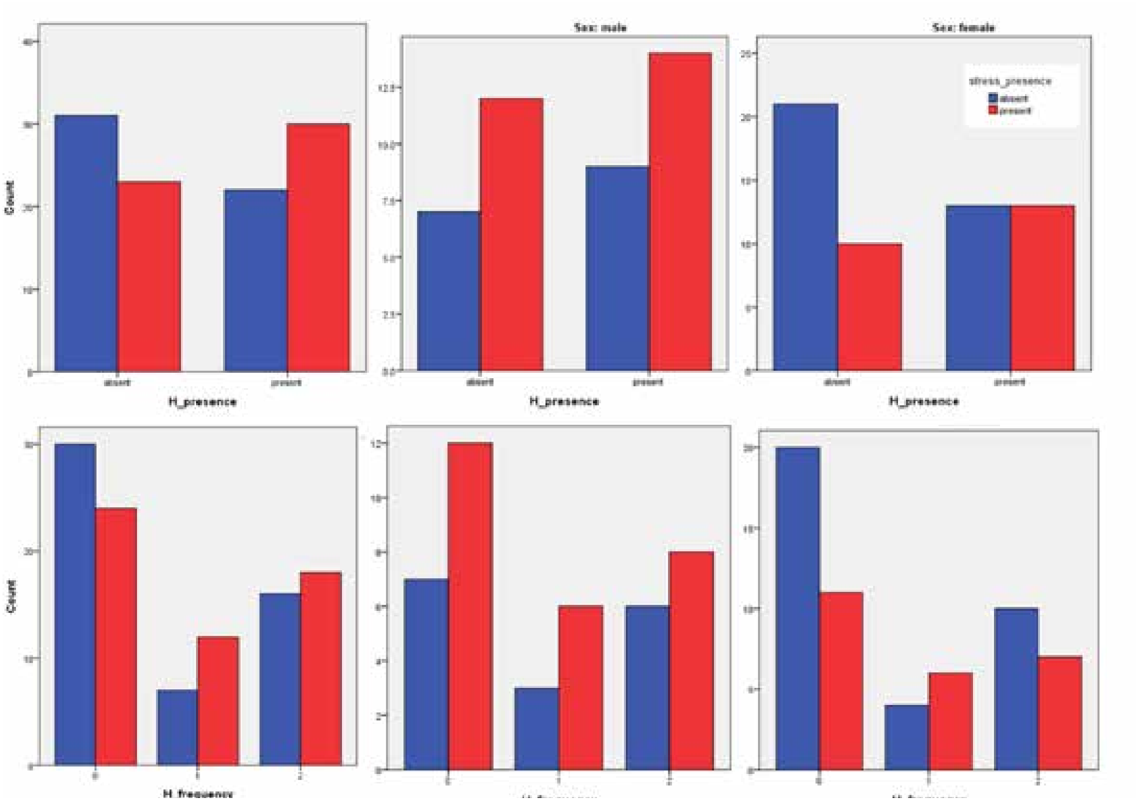

Figure 5. Combined stress markers' presence compared to the presence (upper row) and frequency of enamel hypoplasia. Bar graphs to the left represent the whole sample, the middle ones are for the male and the far right are for the female sample (done using IBM SPSS Software).

DISCUSSION

Our starting hypothesis was that the individuals who survived a period of physiological stress in their childhood would exhibit worse health outcomes later in life (Barker 2004: 31). To test this hypothesis, we observed enamel hypoplasia as a proxy for childhood stress (Goodman and Armelagos 1988; Goodman and Rose 1990; King, Humphrey and Hillson 2005; Lukacs, Nelson and Walimbe 2001; Minozzi *et al.* 2020), while osteological markers of stress, including *cribra orbitalia*, porotic hyperostosis, and periostosis, were examined in the skeletal remains of our study sample. To ensure the absence of confounding factors, we controlled for age-at-death and subsequently employed the collected data to validate our hypothesis.

Upon independent analysis, both *cribra orbitalia* and periostosis displayed no statistically significant correlation with the presence or frequency of enamel hypoplasia. Put differently, individuals who exhibited enamel hypoplasia as an indicator of childhood stress did not demonstrate a heightened likelihood of developing *cribra orbitalia* or periostosis in adulthood. This finding held true for the entire study sample, as well as for each gender subgroup.

Among the 101 individuals whose remains were sufficiently preserved to allow for the detection of *cribra orbitalia*, only 21 individuals exhibited this pathology, with 9 of these individuals presenting no signs of enamel hypoplasia and the remaining 12 individuals displaying both *cribra orbitalia* and enamel hypoplasia. While the sample of individuals with *cribra orbitalia* was relatively homogenous, it was comparatively small, and although Kendall's tau suggested a weak positive correlation, the results of the analysis did not reach statistical significance.

In contrast, periostosis proved much more challenging for this analysis, due to the state of preservation of the skeletal material. As a marker of unspecified osteological stress (as opposed to the periostosis associated with local infection or fracture remodelling, for example) periostitis is

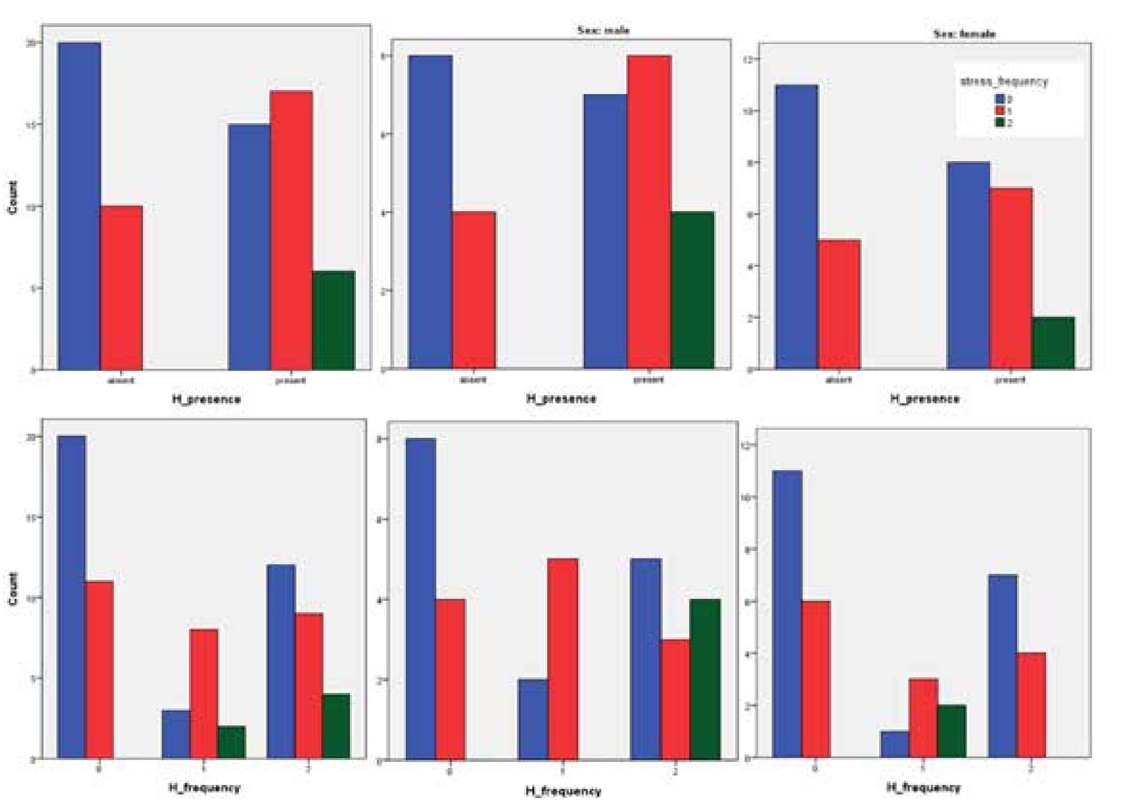

Figure 6. Combined stress markers' frequency compared to the presence (upper row) and frequency of enamel hypoplasia. Bar graphs to the left represent the whole sample, the middle ones are for the male and the far right are for the female sample (done using IBM SPSS Software).

most commonly found in the long bones of the extremities (Ortner 2003: 53). However, the absence of long bones or a lack of periostosis evidence in the present long bones does not necessarily indicate the absence of periostosis in an individual, since the missing long bones could potentially possess evidence of the pathology. Consequently, such individuals had to be excluded from our sample, which, in turn, reduced the robustness of our results.

Porotic hyperostosis was the only skeletal stress marker that showed a statistically significant correlation with the presence and frequency of enamel hypoplasia in our sample. However, the caveat to this finding is the modest sample size, as only 7 out of the 112 individuals included in the analysis presented with porotic hyperostosis. All 7 of these individuals displayed enamel hypoplasia as well, and were uniformly divided between sexes, with 3 males and 4 females affected. This outcome is noteworthy, especially when taking into account that *cribra orbitalia* did not demonstrate a similar correlation. One possible explanation is that the anaemias associated with the occurrence of *cribra orbitalia* and porotic hyperostosis were symptoms of different illnesses (Rivera and Mirazon Lahr 2017: 17; O'Donnell 2019: 10; O'Donnell *et al.* 2020: 8–9). Additionally, given the extent of statistical testing performed on this sample, and considering that the correlation between porotic hyperostosis and enamel hypoplasia only achieved statistical significance when comparing the entire sample and women with the presence of enamel hypoplasia or men with the frequency of enamel hypoplasia, this result may be a statistical coincidence.

The utilization of consolidated variables for analysing the correlation between enamel hypoplasia and osteological markers of stress proved to be the most promising approach. Using these consolidated variables, we were able to test for a correlation between the presence and frequency of enamel hypoplasia and the presence and frequency of osteological markers of stress, regardless of their type. What we lost in precision we gained in the enlarged sample and broadened scope of the health status analysis. The consolidated variable of the presence of osteological markers of stress was defined in this study as being present if an individual exhibited any of the osteological markers of stress that were analysed. The consolidated variable of frequency, on the other hand, noted the number of different types of osteological markers of stress that were present in each individual. It should be noted that individuals who could not be observed for one or more of the osteological markers of stress were excluded from the sample in order to ensure the accuracy of the results.

The consolidated variable of the presence of osteological markers of stress did not demonstrate a statistically significant correlation with the presence, but it did show a positive correlation with the frequency of enamel hypoplasia, which was significant. Interestingly, when divided into groups by sex, the results again show a positive correlation, which was marginally significant for the male sample, but not statistically significant for the women. One explanation could be that there are different mechanisms influencing male and female health status that could stem from both fertility or horizontal and vertical social status, but the more likely explanation is the small sample size (31 for the male sample and 33 for female). The small sample size does not exclude other influences, but those would be hard to prove with such a limited number of individuals.

On the other hand, the consolidated variable of the frequency of osteological markers exhibited a marginally statistically significant positive correlation with both the presence and frequency of enamel hypoplasia. The same trend found with the first consolidated variable was apparent here as well – when testing the whole sample and the male sample, a marginal significance is there, but the result of the female group is, yet again, statistically insignificant. The sample size is the same as with the previous test (31 males and 33 females), so we could apply the same logic as with the consolidated variable of the presence of osteological markers – the sample size precludes us from drawing any meaningful conclusions on the potential differences of health status between men and women without further analyses.

Based on our results, it is clear that relying on a single or just a few osteological markers of stress is overly ambitious when attempting to assess the health status of an individual. While useful in other analyses, osteological markers of stress, which already lack a clear etiology in most (if not all) cases, cannot provide a comprehensive picture of a person's health on their own. Even putting aside the problems stemming from the preservation status of skeletons, which could be poor, especially for prehistoric populations, the mere absence of osteological markers of stress does not necessarily mean that the individual in question did not suffer a disease invisible to physical anthropology. However, the constraints of archaeological material and limitations of currently available methodologies in bioarchaeology should not discourage us from pursuing viable ways of using the data that we can gather and quantify. As demonstrated by our analysis of the consolidated variable of the frequency of osteological stress markers, a macroscopic approach can be sufficient, particularly when dealing with a limited sample size. Although this method does involve some loss of information and a simplified view of an individual's health, it can still be valuable when assessing the health status of a population.

CONCLUSION

In our study, the results suggest that those individuals who survived multiple stress episodes during childhood, indicated by the presence and higher frequency of enamel hypoplasia, had comparatively worse health outcomes, indicated by a higher frequency of osteological markers of stress, than those individuals who did not experience childhood stress. This result is in line with the DOHaD hypothesis, which posits that surviving childhood stress leads to negative health outcomes later in life. It should be noted that using a single osteological marker of stress for this type of health status analysis proved to be too ambitious. Due to sample size constraints at this moment, we cannot offer any meaningful conclusions regarding the potential differences in the health status of the men and women of this population.

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Odnos zdravstvenog statusa i društvenog položaja u bronzanodopskoj kulturi Moriš: nekropole Mokrin i Ostojićevo/Relationship between health and social status in the Bronze Age culture of Maros: Mokrin and Ostojićevo necropolises, and was defended at the Faculty of Philosophy, University of Belgrade, in July 2022.

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REZIME

BOLJI ZUBI, BOLJE ZDRAVLJE? ODNOS IZMEĐU HIPOPLAZIJE ZUBNE GLEĐI I SKELETNIH MARKERA STRESA U RANOBRONZANODOPSKIM POPULACIJAMA SEVERNE SRBIJE

KLJUČNE REČI: HIPOPLAZIJA ZUBNE GLEĐI, SKELETNI MARKERI STRESA, DOHaD HIPOTEZA, ZDRAVLJE, RANO BRONZANO DOBA, KULTURA MAROŠ.

Rano i srednjebronzanodopska kultura Maroš bila je predmet mnogih arheoloških istraživanja koja su imala za cilj odgovoriti na pitanja društvenog usložnjavanja, statusa i načina života. Arheološki i skeletni materijal s nekropola Mokrin i Ostojićevo više puta je korišćen da odgovori na pitanja o statusu, ishrani, fizičkoj aktivnosti i srodstvu. Iako su neki aspekti života nosioca maroške kulture postali jasniji, neophodne su detaljnije informacije o zdravstvenom stanju ovih bronzanodopskih populacija za dublje razumevanje društvenih mehanizama i normi kulture Maroš.

Ovaj rad bavi se pitanjem zdravstvenog statusa populacija sahranjenih na nekropolama Mokrin i Ostojićevo oslanjajući se na skeletne markere stresa i hipoplaziju zubne gleđi. Naša hipoteza drži da su individue koje su u detinjstvu preživele epizodu stresa, koja je ostala zabeležena kao defekat gleđi, posledično imale veće šanse da svoju uvećanu osetljivost na infekcije i bolesti ispolje kroz veću prisustnost skeletnih markera stresa. Analiza je uređena uzimajući u obzir teoriju osteološkog paradoksa, te uz kontrolisanje starosti inidividua, prateći korelacije između hipoplazije zubne gleđi i kribre orbitalije, porotične hiperostoze i periostoze.

Rezultati ukazuju da svođenje zdravstvenog statusa na praćenje samo jednog skeletnog markera stresa nije odgovarajući pristup, posebno kod relativno malih skeletnih serija. Analize koje su

se koristile konsolidovanim varijablama prisustva i frekvencije skeletnih markera pokazale su se kao bolji pristup. Učestalost osteoloških markera stresa dalo je statistički značajnu korelaciju sa prisustvom i učestalošću hipoplazije zubne gleđi, te ukazuje na važnost praćenja više različitih markera stresa prilikom procenjivanja skeletnog statusa populacija u prošlosti.

* * *

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