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BIOARCHAEOLOGY – a discipline that encompasses the past, present and future of mankind

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Abstract

In the past, archaeology was less concerned with the study of human skeletons than with the analyses of the artefacts recovered from archaeological sites. Over time, the importance of a targeted scientific research of the recovered human remains has become apparent leading to the development of different scientific disciplines dealing with the analysis and interpretation of human skeletal remains. One of these is bioarchaeology – a branch of physical anthropology that studies human remains recovered from archaeological sites. This review article presents the main differences between bioarchaeology and other physical anthropology branches, and offers a glimpse into current methods and concepts in bioarchaeology.

The second part of the review deals with the development of the discipline in Croatia. Besides offering a historical review of the individuals that contributed to the development of this field, we also highlight important current bioarchaeological resources, particularly the rich Osteological collection of the Croatian Academy of Sciences and Arts. This collection currently contains the remains of over 6500 skeleton dated from the Neolithic to the Modern Period with important examples of traumatic and pathological cases and thus represents an irreplaceable study material for current and future bioarchaeological projects and collaborations.

Finally, in the closing part of the paper we reveal and discuss the preliminary results of ongoing bioarchaeological research that deals with the effects that endemic warfare had on the health of Historic period populations in Croatia and through this highlight the importance of bioarchaeology and its unique ability to, through the study of our past, allow a better understanding of the present, and therefore better planning of our future.

INTRODUCTION

Different scientific disciplines, related both to the biological and humanistic fields, are nowadays concerned with the study of human remains recovered from archaeological or forensic contexts. In general they represent different subfields of the anthropological discipline known as biological or physical anthropology which, through the analysis of human and primate bones, provides clues on human evolution and biological variation *(1)*. Over time, biological anthropology has divided into several branches, among which the most recognized are palaeoanthropology, bioarchaeology, and forensic anthropology *(1)*. While sharing the same study material (human remains), methods, and very similar or in some cases identical research protocols and standards, these branches differ considerably in their scope. Palaeoanthropology is

primarily concerned with fossilized remains and human evolution, forensic anthropology with the identification and determination of cause of death of recent human remains, while bioarchaeology studies past human lifestyle through the analysis of human remains recovered from archaeological sites. Different to some other biological anthropology subfields, whose work takes place specifically and exclusively in laboratory settings, bioarchaeology is inextricably linked to the field and the archaeological clues that emerge at archaeological sites. By combining methods and concepts from human biology, paleopathology and archaeology, bioarchaeology allows a contextual analysis of past human populations *(2, 3)*. It reconstructs the osteobiography of people who died in the past, relying on facts and material evidences that have emerged from the field and laboratory, and uses agglomerations of these data to interpret the sometimes very complex interactions that exist between cultural and biological factors. Bioarchaeology also takes full advantage of methodologies and scientific techniques and protocols developed by other scientific fields (for example DNA analyses, stable isotope analyses etc) to bring to light new information relevant to the reconstruction of a person's past life and lifestyle *(3, 4)*.

This review will present principal bioarchaeological methods and concepts, provide an insight into the development and achievement of the discipline in Croatia, revealing its great potential for international cooperation and recognition, and provide some preliminary data on a problem that currently affects a large proportion of the World's population and that has afflicted Croatia for more than 300 years – the effects that endemic warfare had on the health of the populations that it afflicted.

BIOARCHEOLOGICAL METHODS AND CONCEPTS

The main task of any bioarchaeologist is to collect and interpret scattered and often fragmented pieces of evidence that will bring to light data necessary for the reconstruction of someone's osteobiography. The agglomeration of these data from an archaeological site afford a holistic view of the quality and means of life of a community and/or past population (when human skeletal assemblages do represent a population) *(5)* or, alternatively, if enough historical data is available, they open up a window into the life of prominent or important historical figures and individuals (revealing often hidden facts and curiosities about their lives and deaths) *(6)*. Regardless of whether the subject of analysis is one individual, or a whole community, a bioarchaeologist always relies on the same array of anthropological techniques and methods which she/he combines with those developed by other disciplines. This multidisciplinary approach to the analysis of human skeletal remains allows the bioarchaeologist to rely on methods that range from simple visual and metrical analysis of bones *(7)* to more complex imaging, engineering, chemical and molecular analyses of skeletal compounds and related artefacts *(4)*.

By using a vast array of methods and techniques a bioarchaeologist tries to collect as much information as he/she can on a persons' life. In this context, usually the first step is to reconstruct the (i) **biological profile** of the collected human remains *(8)*. The biological profile represents a set of biological features that define an individual and includes the sex, ancestry, age at death and height of a person. In this very first phase of work, the bioarchaeologist relies mostly on simple visual and metrical techniques, clearly defined and reviewed in standard procedure manuals *(7, 9)*. The reconstruction of the biological profiles of a skeletal assemblage allows a reconstruction of the demographic characteristics and their potential changes in a past community/population. Besides basic biological data, a bioarchaeologist can also gain information on the (ii) **health and quality of life** of a person by interpreting the specific and non-specific osseous and dental indicators of stress and disease. Specific pathogens or the pathophysiological cascade provoked by some diseases (infectious, metabolic, congenital and neoplastic) usually leave specific signatures on skeletal or dental material *(10, 11)*. A proper interpretation of these markers can help to reconstruct the epidemiology of a disease in the past, data that is important if we wish to better understand the effects that this, or similar diseases, can have on populations today *(12, 13)*. In this we are, unfortunately, hampered by the fact that not all disease cause changes in the human skeleton and consequently, without soft tissue preservation, we cannot gain information on all disease processes in the past. Besides evidence of pathological processes, bones can also exhibit changes that allow us to uncover important information on the (iii) **lifestyle and behaviour** either of an individual, or in a community. These changes include different indicators of chronic physical stress such as Schmorl's nodes in the vertebral bodies and benign cortical defects at the insertion sites of large muscles *(14)*. Additionally, data on the ante- and perimortem trauma can reveal the level of interpersonal violence present in a community *(15)*. Dental analyses and stable isotope analysis of elements that comprise plant and animal tissues (such as carbon, nitrogen, hydrogen, oxygen, strontium) reveal important information on the (iv) **diet and nutritional habits** of a person through his life as well as data on his/her geographical affiliation and movements *(4, 16)*. Finally, there is growing emphasis in contemporary bioarchaeological analyses on different types of molecular DNA analyses that are carried out in order to better understand community familiar patterns, objectively test the sex of skeletal material and most importantly to investigate human migration and population movements in the past *(16, 17)*.

BIOARCHAEOLOGY IN CROATIA – PAST AND PRESENT

While the modern concept of bioarchaeology has been coined as late as 1977 by Jane Buikstra *(1)*, a bioarchaeological approach to the analysis of human remains has existed long before that, and can be found in earlier studies conducted by many biological anthropologists.

In Croatia, the official beginning of bioarchaeology is linked to the discovery of skeletal remains of Neanderthal human beings, better known as Krapina Prehistoric man by Dragutin Gorjanović Kramberger in 1899 *(18)*. This discovery marks the beginning of both paleoanthropological and bioarchaeological studies in Croatia. Kramberger's landmark studies not only revealed the role that these prehistoric men played in human evolution, but also gave a glimpse into their personal lives and deaths. Apart from this, by combining different methods, developing new ones, and implementing pioneering technologies such as X-ray analysis (only a couple of years after its discovery) in the analysis of the recovered human and animal remains, and – even more importantly, by interpreting these data in the context of the recovered artefacts Gorjanović Kramberger showed a very open, multidisciplinary approach to the study of these remains, indicative of a true bioarchaeological way of thinking at the beginning of the 20th century *(19, 20, 21)*. Unfortunately, this sensational discovery was not followed by the development of a school of bioarchaeological studies, and the next studies of this nature appeared in Croatia following the end of the Second World War. These studies primarily focused on the analyses of human remains from medieval archaeological sites with particular emphasis on craniometric analyses of the recovered skulls and were carried out by Franjo Ivaniček and Georgina Pilarić *(22)*. Unfortunately, these studies failed to generate much interest from either the international or Croatian scientific communities. In the early nineties of the last century bioarchaeology regained its popularity in Croatia primarily because of the strong support given to it by the local anthropological community through the Croatian Anthropological Society and the anthropological journal Collegium Antropologicum *(18)*. The tireless work of these anthropologists, headed by Pavao Rudan and Hubert Maver led to the founding of the Institute of Anthropology in 1992 *(23)* and more recently the Anthropological Centre of the Croatian Academy of Sciences and Arts (formerly part of the Department of Archaeology of the Academy) *(18)*, where most of the current bioarchaeological projects are being conducted.

Contemporary Croatian bioarchaeologists analyse human remains recovered from archaeological sites that are dated from the Mesolithic to the Modern period *(18)*. Researcher focuses on demography, stress and pathology, and trauma analyses. A great advantage of the Croatian bioarchaeological community is the existence of a large human skeletal collection. This collection was founded in 1991 and currently contains the remains of over 6500 skeletons (150 pertaining to the Prehistoric period, 2000 to the Antique period, 3 000 to the Medieval period and 1700 to the Historic/Modern Age period). The collection is continually being updated with newly recovered skeletal material *(18)*. These skeletons represent a unique research facility and offer a window into the past of Croatia *(25)*. The collection contains skeletons from both individual and mass graves that exhibit a wide variety of pathological changes that include clear osteological evidence for tuberculosis (Figure 1), leprosy (Figure 2),

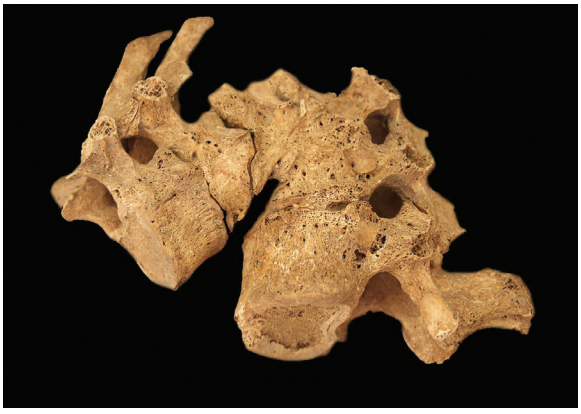

Figure 1. *Osteological evidence for spinal tuberculosis. There is complete destruction of the vertebral bodies of the 7^{h}, 8th, and 9th thoracic vertebrae resulting in a sharp-angled kyphosis also known as Pott's gibbus. The changes were present in an adult female recovered from the Nin – St. Anselm cemetery whose use is dated to the Late Medieval Period.*

Figure 2. *Advanced stage of lepromatous leprosy (facies leprosa) characterized by severe resorption of the central maxilla accompanied by enlargement of the nasal aperture in an adult male recovered from the Early Medieval Radašinovci cemetery in Dalmatia.*

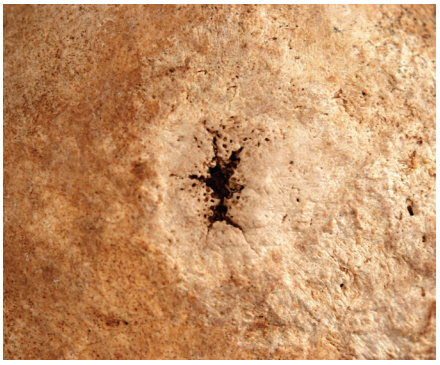

Figure 3. *Well defined stellate scar on the frontal bone of an adult male from the Utvrda Sokol site in Konavli near Dubrovnik. Radiocarbon dating of this individual indicates that he lived during the 17th century. The scar is slightly depressed, sclerotic and radially grooved and represents a healed individual focus of caries sicca on the skull that is indicative of tertiary syphilis.*

Figure 4. *Ankylosing spondylitis in an adult male from the Late Medieval site Koprivno. The spine of this individual exhibits clear evidence of ankylosing spondylitis or Marie-Strûmpell's Disease. The following vertebrae are fused: C3 through C7, as well as T3 through T10. In addition, T5 through T10 are fused with the corresponding right ribs, while T4 through T7 are fused with the corresponding left ribs. All of the vertebrae exhibit preserved but narrowed intervertebral spaces and developed marginal syndesmophytes.*

syphilis (Figure 3), rheumatic diseases (Figure 4), as well as numerous examples of ante- and perimortem trauma (mostly sharp-force and blunt injury trauma, Figures 5-7), making it a unique source of information, important both

Figure 5. *Antemortem blunt force trauma located in the cranium of an adult male from the Late Medieval Kozica cemetery in Dalmatia.*

for bioarchaeological and forensic anthropology studies *(25)*. It is, therefore, no surprise that this collection is used by both national and international colleagues (at present data from this collection has been utilized in the completion of 15 Graduate, 5 Masters, and 7 PhD thesis in Croatia and one Maters and 3 PhD thesis in the USA) and utilized in a large number of international scientific projects. These projects include the joint Smithsonian Institution – Croatian Government project „Development of a Forensic Data base at the University of Zagreb" funded by the Government of the Republic of Croatia and the State Department of the USA through the Smithsonian Institution (from 1995-2000); the collaborative project: ''Development of an archaeological, bioarchaeological and paleontology database for Croatia" (from 2003-2007), a project that consisted of six projects from the fields of archaeology, anthropology, paleontology and linguistics and was funded by the Ministry of Science,

Figure 6. *Perimortem trauma to the left temporal region of the skull in an adult male recovered from the Udbina cathedral. This individual likely perished in the Battle fought on the field of Krbava in 1493 between a Croat army led by Ban Derenčin and a large force of Ottoman akndji led by Jakub paša. This injury may have been inflicted by a mace.*

Figure 7. *Perimortem trauma to the second, third, and fourth thoracic vertebrae in an adult male also recovered from the Udbina cathedral archaeological site. The injuries were clearly inflicted with a sharp edged weapon most likely a sword or saber.*

education and sports of the Republic of Croatia; the project: „Bioarchaeological analyses of medieval populations from Croatia“ (from 2007-2013) and the project ''The effects of endemic warfare on the health of Historic period populations from Croatia'' (from 2014-2018) funded by the Croatian Science Foundation.

CURRENT BIOARCHEOLOGICAL WORK IN CROATIA – USING THE PAST TO DEAL WITH THE PRESENT AND UNDERSTAND THE FUTURE

To illustrate the type of bioarchaeological research currently being carried out in Croatia, as well as the contemporary relevance of bioarchaeology as a discipline, we will conclude this overview with an example of preliminary bioarchaeological research that pertains to a problem that severely affects the modern world. This problem is endemic warfare.

Warfare has afflicted humankind throughout its long history, and is a phenomenon that, unfortunately, still fundamentally affects the modern world. Despite the fact that violence-related mortality is profoundly undercounted, violent conflict represents the third most important source of mortality around the world *(26)*. Recent history has, however, seen three fundamental changes in the nature of war: a) a significant increase in the number of wars, b) a significant increase in the duration of these wars and, c) a discernible shift from external to internal wars – at the end of the twentieth century two-thirds of the world's wars were internal or domestic wars, a type of war characterized by low-intensity, endemic warfare that the international community is still struggling to develop the strategies and mechanisms to deal with effectively *(27)*. Cumulatively, these changes have prompted Gantzel to note that ''…war is becoming a ''normal'' feature of global development" *(27)*. This fact is, if anything, truer in the first decades of the twenty-first century as witnessed by the numerous conflicts, rebellions and revolutions in Afghanistan, Iraq, Algeria, Morocco, Tunis, Libya, Syria, Egypt, and Columbia to name just a few.

There is a growing body of literature demonstrating the broad health consequences of the low-intensity endemic warfare that has become pandemic since the mid-twentieth century *(26, 28-31)*. These scholars highlight the need for more research on violence, inequality, and health, particularly research that makes careful temporal and spatial distinctions, including those between communities that are, or are not, directly affected by violence, and between types of war-affected communities. These concerns have led to the organization of the Global Response international conference on violent conflict and health worldwide that was held in Copenhagen in 2010 where representatives from leading academic institutions, civil society organizations, and the UN including: Harvard, Yale, Oxford universities, UNHCR and WHO, IPPNW, Red Cross and Doctors without Borders, attempted to identify the common causes of violent conflicts and ill health. Prior to the conference the scientific journals: *The Lancet*, *Social Science & Medicine,* and the *Journal of the Danish Medical Association* had published themed issues related to the conference theme of violent conflict and health.

Of importance to scientists studying the effects that warfare has on health is, of course, the fact that warfare is not a new phenomenon. Wars, initiated for whatever reason, have affected the grand epochs in history and have taken place at all times, and in the greatest variety of circumstances. They have involved tribal, national and class levels and have been caused by climatic, political, economic or religious reasons.

Analyzing the effects that war had on health through the deep time perspective that archaeological investigations afford can provide unique data on the interactions between warfare, health and the environment and provided conclusions that are particularly relevant to disadvantaged communities throughout the developing world where most wars are currently being fought. There is no doubt that inferences about past lifeways can successfully be utilized to better inform decisions in the present and future. Using interdisciplinary approaches it is now pos-

TABLE 1
The sex and age distributions in the analyzed series.

	pre-Ottoman				Ottoman			
	Subadults	M	F	Total	Subadults	M	F	Total
0-15	92				133			
15-30		30	31	61		34	26	60
31-44		55	45	100		86	49	135
45+		23	19	42		54	29	83
Total		108	95	203		174	104	278
TOTAL		295				411		

TABLE 2
The sex and age distributions of fracture frequencies calculated by skeleton.

	pre-Ottoman				Ottoman			
	Subadults n/N %	M n/N %	F n/N %	Total n/N %	Subadults n/N %	M n/N %	F n/N %	Total n/N %
0-15	1/92 1.1				5/133 3.8			
15-30		2/30 6.7	0/31 0.0	2/61 3.3		9/34 26.5	7/26 26.9	16/60 26.7
31-44		15/55 27.3	5/45 11.1	20/100 20		20/86 23.2	9/49 18.4	29/135 21.5
45+		3/23 13.0	2/19 10.5	5/42 11.9		16/54 29.6	6/29 20.7	22/83 26.5
Total		20/108 18.5	7/95 7.4	27/203 13.3		45/174 25.9	22/104 21.1	67/278 24.1
TOTAL				28/295 (9.5)				72/411 (17.5)

sible to study the way of life of past peoples in unprecedented detail, delineating diverse dietary and economic strategies, community organization patterns, and health experiences *(32-34)*.

Croatian archaeological sites provide a unique opportunity to study the effects that endemic warfare had on the health of the populations it afflicted because of the fact that from the beginning of the 15th century, and particularly after the Ottoman conquest of Bosnia in 1463, Croatia came into contact with the rapidly expanding Ottoman Turkish Empire. Further Ottoman advance into Croatian territory followed rapidly until by 1604 most of Croatia was under Ottoman rule. The whole period between 1400 and 1699, when the Treaty of Karlowitz, that marks the end of Ottoman control in most of Central Europe and the beginning of the empires gradual stagnation was signed, is characterized by endemic warfare. The main features of this low-intensity warfare was guerilla style warfare carried out by irregular infantry units ("uskoci", "hajduci" and "martolozi") and irregular light cavalry units of the Ottoman army known as "akinji" who employed superior mobility and guerilla style tactics to plunder, take captives and attack trading centers and routes in order to disrupt enemy supply and transportation, and generally terrorize local populations in an attempt to depopulate an area before the advance of regular Ottoman forces *(35)*. Contemporary chroniclers describe the depredations carried out by the akinji in considerable detail noting the years in which the raids were carried out (just for the period between 1400 and 1500 a total of 37 raids were documented in Dalmatia), and by the number of individuals and livestock carried off *(36)*. Thus, one raid carried out in 1415 resulted in the capture of 30 000 individuals *(37)*, another in 1471 in the capture of 20 000 individuals and 80 000 livestock, and another in 1500 in the capture of 3 000 individuals and 2 500 livestock *(38)*.

What is evident from these data is the repetitive nature of akinji raiding and the fact that the number of captured slaves and livestock decreased with time as local barons begin to organize themselves against the attacks.

In this overview we will concentrate on the effects that this low intensity type of warfare had on trauma frequencies and distribution. Based on previous, limited analyses of individual cemeteries *(39)*, and the available historical literature, a reasonable hypothesis is that an increase of trauma levels is expected in the period from 1400-1700 resulting from guerilla warfare and insistent Akinji raiding. An additional question that needs to be addressed is: what segment of a community was most affected by endemic violence? At first glance it would appear to be logical that in scenarios where violent conflict is frequent males would be the most affected group. However, previous analyses *(39)* have shown that even when only perimortem trauma frequencies are analyzed, males can be significantly less affected than females.

To answer these questions two large composite skeletal samples from Croatia are analyzed for the presence of trauma: an earlier pre-Ottoman (1100-1400 AD), and a later, Ottoman (1400-1700 AD) sample (Table 1). All of the analyzed sites are located in continental Croatia. The pre-Ottoman sample consists of 295 skeletons from four archaeological sites: Stenjevec, Zvonimirovo, Suhopolje, and Đakovo. Based on grave goods and vertical and horizontal stratigraphy use of all four sites is dated to the period between 1100-1400 AD. The Ottoman sample consists of 411 skeletons from three archaeological sites: Čepin, Torčec, and Virje. Grave goods and radiocarbon dating dates the use of these cemeteries to the period between 1400-1700 AD. All of the skeletal material is curated in the Osteological collection of the Croatian Academy of Sciences and Arts.

The age-at-death of the recovered individuals was determined using methods described in Buikstra and Ubelaker for adul1ts *(7)*, and Scheuer and Black (2004) for subadults *(40)*. Individuals were grouped into one of following age categories: subadults (between 0 and 14 years), young (between 15 and 30 years), middle-aged (between 31 and 45 years), and old (45+ years). Sex was estimated only for adults based on cranial and pelvic morphology *(7)*. Only individuals with unambiguous age-at-death and sex estimation were included in the sample.

All of the skeletal material was carefully examined macroscopically for evidence of trauma according to criteria outlined in Šlaus *et al. (39)*. The presence of trauma was determined by checking for bilateral bone asymmetry, angular deformities, and the presence of bone calluses. Each trauma was described in detail and its location and dimensions were noted. No distinction was made between ante- and perimortem skeletal injuries.

Fracture frequencies per skeleton for subadults and adults are shown in Table 2. In the pre-Ottoman sample the total fracture frequency for all analyzed individuals is 28/295 or 9.5%, while in the Ottoman period sample the frequency is significantly higher (72/411 or 17.5%; χ^2 = 9.1, df = 1, P = 0.0026). When the sample is broken down by sex and age the same trend, without achieving statistical significance is noted in subadults (1/92 or 1.1% in the pre-Ottoman sample, compared to 5/133 or 3.8% in the Ottoman sample). Total adult frequencies mirror this with the distinction that Ottoman series frequencies are significantly higher (27/203 or 13.3% in the pre-Ottoman series, compared to 67/278 or 24.1% in the Ottoman series; χ^2 = 8.7, df = 1, P = 0.0032). These results are not unexpected and confirm the fact that, unsurprisingly, incessant raiding and endemic warfare significantly increases trauma frequencies. Of greater interest is the fact that when the adult sample is broken down by sex, the increase in male trauma frequencies, while clearly evident, is not significant (20/108 or 18.5% in the pre-Ottoman, compared to 45/174 or 25.9%. in the Ottoman period series; χ^2 = 1,63, df = 1, P = 0.201) while that of females is (7/95 or 7,4% in the pre-Ottoman, compared to 22/104 or 21.1% in the Ottoman period series; χ^2 = 7.57, df = 1, P = 0.0059). These data suggest either that females were intentionally targeted in raids, possibly for the shock value that this would have on a community when the purpose of the raids was to achieve ethnic cleansing, or were exposed to higher levels of trauma because of a combination of external (akinji raiding and guerilla warfare) and internal (higher levels of domestic violence) factors.

Clearly, additional analyses are necessary to elucidate these results and to identify to what degree, if any, they conform to results of trauma analyses in modern populations exposed to endemic violence.

These results, as well as countless others from a myriad of bioarchaeological analyses carried out on archaeological populations from different parts of the world clearly illustrate how perspectives from the human past can inform decisions in the present to improve human health. There is no doubt that additional, more detailed analyses of our composite samples will lead to a better understanding of the ways in which endemic warfare affects health, information that will be of use to international agencies dealing with the consequences of endemic violence in under-developed and developing regions of the world, particularly in sub-Saharan Africa and Asia, where violence, related to displaced populations, has increased dramatically.

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