

New radiocarbon dates, stable isotope, and anthropological analysis of prehistoric human bones from the Balkans and southwestern Carpathian Basin

Jelena Jovanović¹, Tamara Blagojević¹, Jelena Marković², Mario Novak³, Željka Bedić⁴, Goce Naumov⁵, Elena Stojanova Kanzurova⁶, Dženi Los⁷, Mirela Hutinec⁸, Ljubo Fidanoski⁹, Goran Skelac¹⁰, Mario Šlaus⁴, and Sofija Stefanović²

¹ BioSense Institute, University of Novi Sad, Novi Sad, RS

jelena.jovanovic@biosense.rs; tamara.blagojevic@biosense.rs

² Laboratory for Bioarchaeology, Faculty of Philosophy, University of Beograd, Beograd, RS

jmarkovicc.bg@gmail.com; sofija.stefanovic@f.bg.ac.rs

³ Centre for Applied Bioanthropology, Institute for Anthropological Research, Zagreb, HR

mario.novak@inantro.hr

⁴ Anthropological Centre, Croatian Academy of Sciences and Arts, Zagreb, HR

zeljka.bedic@gmail.com; marioslaus@gmail.com

⁵ Museum of Macedonia, Skopje, MK; gocenaumov@gmail.com

⁶ Archaeological Museum of Macedonia, Skopje, MK; elena_mk2004@hotmail.com

⁷ Kaducej d.o.o., Split, HR; dzenilos@hotmail.com

⁸ Vučedol Culture Museum, Vukovar, HR; mirela.hutinec@vucedol.hr

⁹ Museum of the City of Skopje, Skopje, MK; fidanoskilj@yahoo.com

¹⁰ Geoarheo d.o.o., Zagreb, HR; goran@geoarheo.hr

ABSTRACT – *The paper provides a detailed overview of new radiocarbon dates, stable isotopes, and anthropological information obtained on prehistoric human remains (mostly Neolithic) from the Balkans and southwestern Carpathian Basin. It covers a large chronological sequence from the Mesolithic to the Bronze Age (9746–2628 cal BC), which encompasses different archaeological cultures. In total 76 radiocarbon dates deriving from 27 sites were obtained, coupled with new isotopic (n=34) and anthropological (n=33) data. The results filled the gaps in some of the older interpretations, but also produced new insights regarding chronology, health, and diet, leaving a strong base-line for all future research into Neolithic lifestyles.*

KEY WORDS – *Neolithic; ¹⁴C analyses; stable isotopes; diet; health*

Novi radiokarbonski datumi, stabilni izotopi in antropološke analize prazgodovinskih človeških kosti iz Balkana in jugozahodnih Karpatov

IZVLEČEK – *Prispevek vsebuje podroben pregled novih radiokarbonskih datumov, stabilnih izotopov in antropoloških informacij, pridobljenih iz prazgodovinskih človeških ostankov (večinoma neolit-skih) na Balkanu in v jugozahodni Karpatski kotlini. Zajema dolgo kronološko sekvenco od mezolitika do bronaste dobe (9746–2628 cal BC) v različnih arheoloških kulturah. Pridobljeno je bilo 76 radiokarbonskih datumov skupaj z novimi izotopskimi (n=34) in antropološkimi (n=33) podatki iz 27 najdišč. Rezultati so zapolnili vrzeli v nekaterih starejših interpretacijah in prinesli nove vpoglede v kronologijo, zdravje in prehrano, ki predstavljajo močno izhodišče za vse prihodnje raziskave neolitskih življenjskih slogov.*

KLJUČNE BESEDE – *neolitik; ¹⁴C analize; stabilni izotopi; prehrana; zdravje*

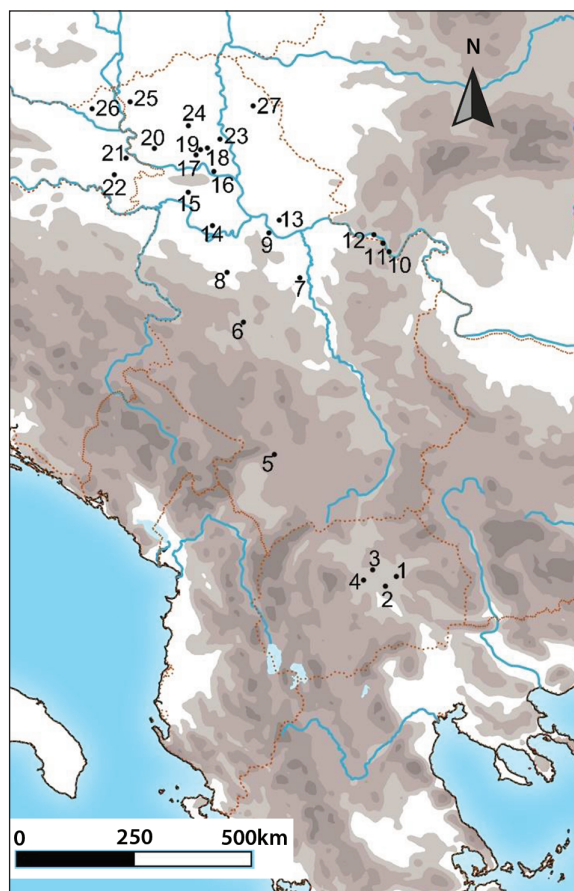
Introduction

During the last few decades there has been a growing body of data on prehistoric radiocarbon dates in the Balkans. The ^{14}C analyses were undertaken as a part of various projects and studies, mainly to establish chronology of the Mesolithic – Neolithic transition, settlement, and demographic patterns, and coupled with stable isotope measurements, to infer dietary habits of Early Holocene communities (Bonsall et al. 2015a; 2015b; Borić 2009; 2011; Borić, Dimitrijević 2009; Mathieson et al. 2018; McPherron et al. 1988; Porčić et al. 2021; Stefanović, Porčić 2015; Tasić et al. 2015; Whittle et al. 2002). One of the latest projects that produced a significant amount of new ^{14}C data on human bones from prehistoric sites is the BIRTH project¹, which focuses on human fertility, health, diet, and population dynamics in the period between 10 000 and 5000 years BC. The main purpose of extensive dating of human osteoarchaeological assemblages within the project was to clarify long-standing debates about the chronology of some sites and burials from the old excavations, and in some cases to confirm the assumed chronological sequence. The latter was of special importance for the assumed Late Neolithic burials, considering their scarce presence in the archaeological record on the territory of the central Balkans and southwestern Carpathian Basin. To date, the only known Late Neolithic cemeteries are those at Botoš (Grbić 1934) and Gomolava (Borić 1996). Another important result of the extensive dating within the BIRTH project is that a complete sample

of human remains discovered up to now is radiocarbon dated and available for further research. The sample consists of the Early and Late Neolithic human remains, primarily from the territory of the central Balkans and part of the southwestern Carpathian Basin. Besides, stable isotope analyses of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ were done together with AMS dates for most of the human remains, which contributed to the better understanding of dietary behaviours of these past communities.

This paper covers a large chronological sequence, which encompasses different archaeological cultures, depending on the region. Samples were chosen for the purpose of different research questions within the BIRTH project, but the common aim was to date all available human remains that could be connected to the Mesolithic sequence of the Lepenski Vir culture (~9500–6300 cal BC; Borić 2011), the Early Neolithic Starčevo culture (~6200–5300 cal BC, Whittle et al. 2002) and the Late Neolithic Vinča culture (~5300–4600/4500 cal BC, Tasić et al. 2015; 2016; Tripković 2011) in the Balkans. Additionally, within the BIRTH project some of the human

Fig. 1. Map of the sites used in this study: 1 Amzabegovo; 2 Govrlevo; 3 Tumba Madžari; 4 Pista Novo Selo – Mamutčevo; 5 Rudnik Kosovski; 6 Gričvac; 7 Zmajevac; 8 Jaričište; 9 Vinča – Belo Brdo; 10 Vlasac; 11 Lepenski Vir; 12 Padina; 13 Starčevo – Grad; 14 Baštine – Obrež; 15 Highway E-70, 521km; 16 Sremski Karlovci – Sonje Marinković 1; 17 Sajlovo; 18 Klisa; 19 Novi Sad – Gornja Šuma; 20 Topole – Bač; 21 Vukovar Gimnazija; 22 Vinkovci Ervenica – Poljski jarak; 23 Gospodinci – Nove zemlje; 24 Zmajevo – Livnice; 25 Bezdan – Bački Monoštor; 26 Beli Manastir – Popova zemlja; 27 Idoš (the base layer was formed out of mosaic SRTM (Shuttle Radar Topography Mission 1 Arc-Second Global (Digital Object Identifier (DOI) number: /10.5066/F7PR7TFT), as available from Earth Explorer site (<https://earthexplorer.usgs.gov/>) by J. Pendić, adjusted by T. Blagojević).



1 BIRTH: Births, mothers and babies: prehistoric fertility in the Balkans between 10 000–5000 BC, funded by the European Research Council (ERC).

remains from neighboring regions were AMS dated. These include the remains from the Early Neolithic Amzabegovo – Vršnik (~6500–5450 cal BC, *Whittle et al. 2005*) and the Late Neolithic Sopot (~5400–3790 cal BC, *Obelić et al. 2004*) culture sites. Several dates (n=4) come from later sequences – Eneolithic, Bronze Age and the Middle Ages, but were originally dated as deriving from the Mesolithic or Neolithic contexts.

Regarding the regional attribution of the sites, four regions have been defined: (1) the southern Balkans, including the sites from modern-day North Macedonia; (2) the central Balkans – including sites located north of the Ibar River, and south of the Danube and Sava Rivers; (3) the Danube Gorges – including sites located on the left bank of the Danube; and (4) the southwestern Carpathian Basin – a region that covers the Pannonian Plain in Serbia and north-eastern Croatia.

In this study we thus present: (i) new radiocarbon dates obtained on human skeletal remains (n=76) from 27 sites dated from the Mesolithic to the Bronze Age (9746–2628 cal BC), with the addition of two Middle Ages dates, from the territory of the southern and central Balkans, and southwestern Carpathian Basin (Fig. 1), and discuss them in the context of individual sites²; (ii) anthropological (n=33) and stable isotope (C_{coll} , N, n=34) analyses of all newly dated individuals, to infer their biological characteristics and dietary strategies. These new data are discussed together with previously published studies. In addition, we present a large set of supplementary data, including methodological details given in [Supplementary Material 1 \(SM 1\)](#), the archaeological contextualization in [Supplementary Material 2 \(SM 2\)](#), and a catalogue of analyzed individuals in [Supplementary Material 3 \(SM 3\)](#). In [Supplementary Ma-](#)

[terial 4 \(SM 4\)](#) the probability distribution plots are given.

It should be emphasized that the aim of this paper is not to offer new interpretations of some of the crucial Neolithic processes or phenomena on a local or regional level. Rather, the aim is to summarize and contextualize a new and large set of data regarding the chronology, health, and diet of the Neolithic communities. In this way, the opportunity is given to challenge or consolidate previous interpretations for some of the specific sites. This represents one part of the outcome of this kind of approach, and it is addressed in this paper directly. The other part is setting the comprehensive baseline for all future research on various subjects with specific research questions regarding the European Neolithic.

Results and discussion

Southern Balkans

Amzabegovo

The resulting date span places the only individual available today from this site in the first half of the Early Neolithic/Amzabegovo–Vršnik culture sequence (6209–6018 cal BC within the 95% CI; [SM 4](#); Tab. 1 in [SM 5](#)). The remains belonged to a neonate, aged 38–40 gestational weeks, who was probably buried with a female interred in Burial 8 (see [SM 3](#) for a detailed description). The neonate had active cribra orbitalia (CO), which could be a consequence of nutritional deficiency of the mother. It is common that pregnant and lactating women develop some nutritional disbalance, usually vitamin B12 deficiency or anaemia (*Walker et al. 2009*). Their babies are therefore born with low vitamin B12 reserves, that are further depleted by the synergistic effects of low vitamin B12 concentrations in the mother's breast milk, coupled with poor living conditions and nutri-

² All the dates from the central Balkans, and almost half of them from the southwestern Carpathian Basin (17 out of 31 dates) obtained on human samples from Early and early Late Neolithic contexts, were used as a part of the study that deals with the population dynamics reconstruction during the Early Neolithic (*Porčić et al. 2021*, see [Supplementary Material 4 \(SM 4\)](#)). These uncalibrated values were used only in the form of the raw data, as a control sample-additional to the main probabilistic sample, designed for the purpose of the aforementioned study. Therefore, the majority of dates in the present study could be considered as being published and discussed thoroughly for the first time in this paper, since they will be discussed in more detail in the context of particular sites. Some of the dates obtained on human remains from the Danube Gorges sites (n=8) will be also published in this paper for the first time. Some of the other dates (n=18) from the Danube Gorges sites are discussed in a study that deals with the plant consumption revealed from human dental calculus analysis and TCA analysis (*Jovanović et al. 2021* (n=17); *Penezić et al. 2020* (n=13)). From the territory of the southern Balkans (modern-day North Macedonia), five new dates on human remains were obtained and published in this study (only calibrated values from the site of Govrlevo have already been published in *Fidanoski 2019*). One Medieval date with stable isotope values from this region, from the site of Vrbjanska Čuka, has been given in [SM 4](#), but was not further discussed since only one tooth which is dated has been preserved from this individual. From the territory of the southwestern Carpathian basin (modern-day Croatia), 12 new dates were obtained during the BIRTH project, out of which 10 will be published in this study for the first time, while 2 dates from the site of Vinkovci Ervenica-Poljski jarak are discussed in the paper by Kristina Penezić *et al.* (2020).

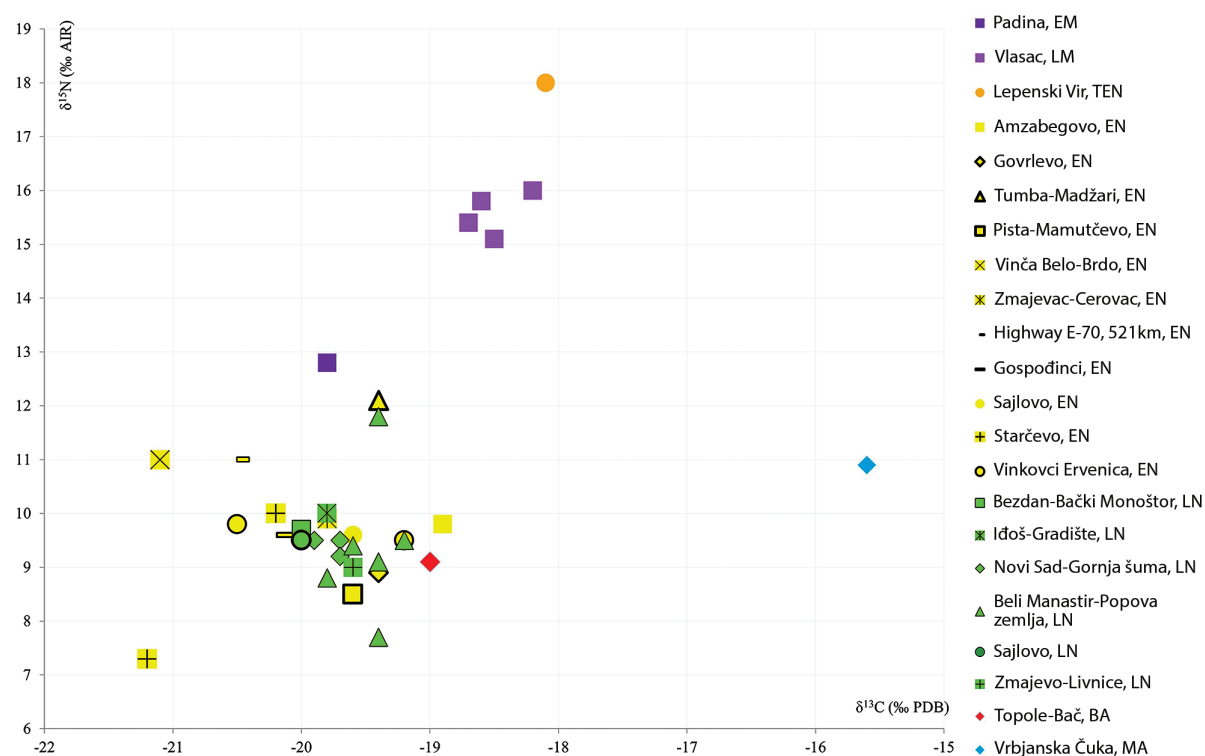


Fig. 2. $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of humans from prehistoric sites performed within this study (EM Early Mesolithic; LM Late Mesolithic; TEN Transformational/Early Neolithic; EN Early Neolithic; LN Late Neolithic; BA Bronze Age; MA Middle Ages).

ent losses from gastrointestinal infections (Walker et al. 2009). Since it is known that the isotopic ratios of neonates reflect the mothers' diet (e.g., Fuller et al. 2006; Kinaston et al. 2009; de Becdelièvre et al. 2015), in this case $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ of neonate (Fig. 2; SM 4) show that the mother probably favoured the consumption of terrestrial proteins (from C_3 plants, meat of herbivores) like most of the Early Neolithic individuals from the region (Whittle et al. 2002; Jovanović 2017; Jovanović et al. 2018). It is possible that at some point the mother had restricted access to animal food, which resulted in developing CO in this infant, since in populations with restricted animal food access, the risks of vitamin B12 deficiency-induced megaloblastic anaemia are greatly increased for infants (Baker et al. 1962; Sandberg et al. 1981; Walker et al. 2009). She also had a $\delta^{13}\text{C}$ value of -18.9‰ , which is the highest value of carbon recorded for one individual from the Balkans during the Early Neolithic (excluding the Danube Gorges sites; Fig. 2; SM 4). At the closest sites of Pista, Tumba – Madžari and Govrlevo, human $\delta^{13}\text{C}$ values range from -19.4 to -19.6‰ , and thus different $\delta^{13}\text{C}$ values from Amzabegovo may perhaps be connected to the different place of the origin of this woman. However, it is hard to conclude what led to this value, since the local animal isotopic baseline is currently unknown.

Most of the other human remains found at Amzabegovo were anthropologically analysed during the 1970s by János Nemeskéri and Imre Lengyel (1976) who concluded that the majority of them belonged to children and juveniles, while among the adults most of them were females. The height has been calculated for only one female (152.4cm), which is relatively short compared to the average stature for females in the Balkans' Early Neolithic (Jovanović 2017). Concerning the health status of the Amzabegovo population, they suffered from similar conditions (e.g., periostitis, osteoarthritis (OA), spondylosis, fractures, nonspecific stress indicators, etc.) like their counterparts living across the Balkans and southwestern Carpathian Basin (Veljanovska 1998; Masson 2014; Jovanović 2017).

Govrlevo

The remains of three Neolithic individuals have been found at this site, and two of them were dated. Within the BIRTH project a fragment of human mandible from the individual marked as bb 1-04 (65) was AMS dated to the middle part of the Early Neolithic sequence (5990–5847 cal BC within the 95% CI; SM 4; Tab. 2 in SM 5). It corresponds well with other Early Neolithic dates from the site, and it is also the oldest one obtained so far (Fidanoski 2019). Since only the left half of the mandible is pre-

served with several teeth within alveolar sockets, the data on age and sex are limited. The ante-mortem loss of one tooth and abrasion indicate that these remains probably belonged to a young adult, between 25 and 35 years old. Supragingival dental calculus of degree 1 has been noted on one tooth which could be related to various factors, such as diet, oral hygiene, or genetics. Isotopic values of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ (Fig. 2; [SM 4](#)) indicate that this individual had a terrestrial diet based on C_3 plants and meat of domesticates/wild game. These data are in accordance with the archaeozoological analysis from this site, which showed that animal husbandry (predominantly sheep, goat, cattle, and pig) played a more important role than hunting (*Ivkovska 2009*). Beside this, one more better-preserved mandible was also found at this site. It belonged to a young adult, and also contains traces of supragingival calculus of degree 1. The appearance of these mandibles could be related to the secondary manipulation of the deceased, or to some ritual deposition. A similar record was noted at the nearby Early Neolithic site of Tumba – Madžari, where one mandible was also discovered (*Stojanova Kanzurova 2020*). The practice of post-mortem manipulation and fragmentation of the body was present in the Mesolithic – Neolithic world in this region (e.g., *Srejović, Letica 1978; Zalai Gaál 1994, 2009; Radovanović 1996; Borić 2015, 2016; Živaljević 2015*), and most instances involved head manipulation. The funerary record from the Danube Gorges contains numerous examples of disturbed primary inhumations with missing body parts, and disarticulated elements (mainly skulls and mandibles) incorporated into later burials, or structurally deposited on their own (e.g., on stone slabs, on/below building floors, or intermingled with animal bones). The deceased were thereby continuously connected with the world of the living (*Borić 2010*). There are also examples from the Late Neolithic, in the Lengyel and Tisza culture, which include the removal of skulls and/or mandibles from the certain individuals, which were sometimes replaced with wild boar mandibles or more rarely dog remains (*Zalai Gaál 1994; 2009*). Such mortuary rites were likely related to some beliefs connected to human-animal relationships, or perhaps to social exchanges. Thus, the findings of these two mandibles at Govrlevo could be perhaps related to some of these practices.

At this site another burial, mostly destroyed by the construction of a house, has also been discovered (*Fidanoski 2013*). Radiocarbon analysis confirmed its Early Neolithic provenience (5979–5735 cal BC

within the 95% CI) (*Mathieson et al. 2018*). Anthropological analysis showed that the remains belonged to a male, aged 25–30 years old (*Veljanovska 2017*). His height was 160cm (*Veljanovska 2017*), which is relatively short and below the average stature for males in the Balkans Early Neolithic (*Jovanović 2017*). The low presence of supragingival calculus could be related to various factors (diet, oral hygiene, or some other factor), while traces of caries suggest he probably had a diet rich in carbohydrates. The appearance of caries is common in the Early Neolithic humans from the region (*Jovanović 2017*), and could be the result of the increased consumption of carbohydrates at the beginning of the Neolithic. Although he had a healed porotic hyperostosis (PH), an active CO indicates that he was suffering from some nonspecific stress until he died, probably caused by anaemia, nutritional deficiency, or poor living conditions. During childhood, this individual also experienced some physiological stress events (e.g., high fever, nutritional deficiency), evidenced by the presence of pit and linear enamel hypoplasia (LEH). According to the ADMIXTURE analysis (*Mathieson et al. 2018*), he had an ancestry from the Near-Eastern Neolithic communities, probably from the region of the north-west Anatolia.

Tumba – Madžari

Several remains of Neolithic individuals have been found at this site (see [SM 2](#)), and only one infant has been AMS dated so far. The resulting date span places the infant's burial in the second half of the Amzabegovo – Vršnik culture sequence (5976–5760 cal BC within the 95% CI; [SM 4](#); Tab. 3 in [SM 5](#)). The infant was found in the flexed position laying on its right side (Fig. 3). Anthropological analysis showed this skeleton belonged to an infant aged 3 to 6 months old (*Veljanovska 1998*). The stable isotope ratios of $\delta^{15}\text{N}$ (Fig. 2; [SM 4](#)) are higher than expected for these communities living in the region, probably due to the breastfeeding effect. However, one cannot exclude that higher levels of $\delta^{15}\text{N}$ ratios are sometimes caused by some physiological factor (disease or nutritional stress prior to death; *Fuller et al. 2005; Neuberger et al. 2013; Robertson et al. 2014*). Since isotopic ratios of neonates reflect the diet of the mother, one can assume, according to the isotopic ratios of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ (Fig. 2; [SM 4](#)), that the mother was probably taking a diet mostly focused on terrestrial proteins (C_3 plants and meat of domesticates and wild game). The interesting finding from this site is a female mandible (*Stojanova Kanzurova 2020*), which, as in the case of Govrlevo findings, could be also related to the secondary



Fig. 3. Remains of a child skeleton (Burial 1/1985), House 4, Tumba Madžari, Skopje (photo archive, Archaeological Museum of Macedonia, Skopje).

manipulation of the deceased, or to some ritual deposition.

Pista – Novo Selo, Mamutčevo

From two Neolithic burials found at this site (see [SM 2](#)), one has been dated. The resulting date span places Burial 1 in the second half of the Amzabegovo – Vršnik culture sequence (5613–5482 cal BC within the 95% CI; [SM 4](#); Tab. 4 in [SM 5](#)). This is in accordance with the archaeological research and previous interpretations, which dated both burials from this site to the Amzabegovo – Vršnik II phase ([Veljanovska 2001](#)).

Anthropological analyses of both skeletal remains from this site shows they belonged to females, between 40 and 50 years old, with similar body height (Burial 1: 161cm; Burial 2: 162cm; [Veljanovska 2001](#)), which is more than the average female stature in the Early Neolithic Balkans and southwestern Carpathian Basin ([Jovanović 2017](#)). They had a strong presence of caries, like many other Early Neolithic humans from the region ([Jovanović 2017](#)). This, coupled with periapical tooth abscesses and several ante-mortem teeth lost ([Veljanovska 2001](#)), can be either a consequence of their diet enriched in carbohydrates, which led to the development of caries and consequently tooth loss, and/or because of their older age. The isotopic ratios of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ (Fig. 2; [SM 4](#)) show that a female interred in Burial 1 had a terrestrial diet based on the consumption of C_3 plants, meat/dairy products (?) of domesticates and wild game. A small amount of supragingival calculus is present on the teeth of both females, probably as a consequence of several factors including diet, oral hygiene and their older age. They both experienced some nonspecific physiological stress dur-

ing childhood as evidenced by traces of LEH ([Veljanovska 2001](#)). Concerning other paleopathological changes, the female interred in Burial 1 had curved femurs and strong platimery ([Veljanovska 2001](#)), which may be a consequence of biomechanical pressure, the specific position that the individual had, or some other factor. The other female had traces of OA and spondylosis on several vertebrae ([Veljanovska 2001](#)), which is in accordance with her older age. Osteolytic lesions detected on the skull ([Veljanovska 2001](#)) could reflect wide range of diseases (e.g., from arachnoid granulations or vascular lacunae to aggressive malignant lesions such as lymphomas or metastases; [Ugga et al. 2018](#)), and therefore their cause remains unknown.

Central Balkans

Grivac

Although very fragmented remains from several individuals have been found at the site (see [SM 2](#)), only two of them are available, of which the better preserved one (Burial 1) has been AMS dated. The results (6073–5997 cal BC within the 95% CI; [SM 4](#); Tab. 5 in [SM 5](#)) confirmed the previous assumption, based mostly on pottery typology, that the site was occupied during the first half of the Starčevo culture sequence. The individual was buried inside the pit in a flexed position. Since the skeleton is poorly preserved, the sex could not be estimated, while the tooth abrasion and degree of sagittal sutures closure indicate the age of ~30 years ([Jovanović 2017](#)). Supragingival calculus was detected on all preserved teeth in a small amount. Isotopic values of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ indicate a mostly terrestrial diet (C_3 plants, domestic and wild herbivores and omnivores) with small input of aquatic resources ([Jovanović et al. 2018](#)). The second individual from this site is a child, 5–10 years old, whose skeleton is also poorly preserved. Detected healed CO with small porosity indicates that the child experienced some nonspecific physiological stress, caused by nutritional deficiency, iron deficiency anaemia or some other factor ([Jovanović 2017](#)). Based on these findings, one can conclude that the diet and health of these individuals was similar to those of their counterparts living in the region ([Jovanović 2017](#); [Jovanović et al. 2018](#)).

Jaričište 1

Four burials have been found at this site (see [SM 2](#)). One of them (Burial 2) has been previously AMS dated ([Stefanović, Porčić 2015](#)), while the second one (Burial 4) has been dated within the BIRTH project. Anthropological analysis showed that five indi-

viduals were found at this site (*O.c.*). While individual from Burial 1 was not available for the analysis, Burial 2 contained two individuals (Individual 1 – child ~7 years of age, and Individual 2 – female ~40 years old). In Burials 3 and 4 the remains of children aged 6 and 3 years, respectively, were found. Previous radiocarbon analysis of a double burial (Burial 2) showed that these burials were not contemporaneous, and that the most probable temporal distance between the two deaths and burials was ~100 years (*O.c.*). However, this difference could have also been caused by a diet rich in aquatic resources. Nevertheless, this discovery gave valuable insights into the Early Neolithic funerary practice. It showed that the same burial place was probably reused, and that the younger burial did not destroy the previous one. It is thus possible that the child was buried intentionally next to the woman who died much earlier (*O.c.*). Within the BIRTH project, a sample of cranium from Burial 4 was AMS dated (5625–5520 cal BC within the 95% CI; [SM 4](#); Tab. 6 in [SM 5](#)). The results indicate that burial was chronologically closer to the burial of a child from the double burial, but most probably not contemporaneous. Individuals buried at Jaričište 1 show poor health status, visible through presence of CO, LEH and PH, indicating a hard childhood and nutritional disbalance (*O.c.*). The youngest child who was AMS dated had the severe presence of CO and very strong meningeal reaction, which was possibly the cause of death. The skeleton of a female shows traces of mild periosteal reaction on the tibia, which is the result of some nonspecific infection, usually not fatal, because it is localised to only one region of the bone. This woman also had the presence of caries and ante-mortem tooth loss, with the teeth perhaps lost because of the presence of caries. The appearance of caries is common in Early Neolithic humans from the region ([Jovanović 2017](#)) and could be due to nutritional changes at the advent of this period. Anthropological analysis revealed the woman was 161.42cm tall, which is more than the average height of Early Neolithic females (*O.c.*).

Vinča – Belo Brdo

At this site a collective burial was found ([Vasić 1932](#); [SM 2](#)), from which seven individuals were AMS dated within a previous study ([Tasić et al. 2015](#)), while within the BIRTH project one fragment from the human skull marked as ‘VI’³ was dated (5556–5475 cal BC within the 95% CI; [SM 4](#); Tab. 7 in [SM 5](#)). The result confirmed the Starčevo cultural sequence. Col-

lective burials are rare in Early Neolithic and Starčevo culture sites, where individual inhumations are the norm ([Chapman 1983; 2006; Tasić et al. 1990](#)). Since its discovery, scholars have mostly debated the architecture of this feature ([Vasić 1932; 1936; Letica 1968; Perić, Nikolić 2006](#)), without questioning if it really represented a burial place. Nine out of ten individuals were found inside the pit, and one was found in the entrance hall. One of the possible causes of death of those people has been considered to be a fire on the roof part of the pit ([Korošec 1950; Mikić 1988](#)).

Recent AMS, anthropological and contextual study of this feature gave a new bioarchaeological perspective ([Jovanović 2017; Stefanović et al. 2016; Tasić et al. 2015](#)). Anthropological analysis showed that the minimal number of individuals was not nine, but 12, all being adults ([Jovanović 2017](#)). New radiocarbon dates indicated a span from 5700 to 5500 cal BC, showing that although some of the deceased were buried at almost the same time, the burial of these 12 individuals did not represent a single event. The reconstruction showed that none of the deceased was buried in a typical Starčevo flexed position (Fig. 4), and that seven individuals were buried in extended positions, and only one on the side. Some of the skeletons (II, III, IX) were placed with the face and chest toward the ground, which is commonly associated with the expression of rejection and taking away the dignity of the deceased ([Arcini 2009](#)). One of the alternative scenarios is that maybe those individuals died during sleep, due to the suffocation which resulted from fire. However, this scenario is questionable since there are no traces of burning, except on Skeleton I, which likely occurred post-mortem. The re-analysis of the skeletal remains showed that Starčevo group burial could represent a crime scene ([Jovanović 2017](#)). Traces of violence were detected on skulls II (a small fracture on the occipital bone), VI (trace of blunt force trauma on the left parietal bone) and VIII (dislocated skull, the chest placed toward the ground, left leg placed on the back, which was not possible without dismembering the leg, while right leg was contracted with a broken femur).

Since most individuals found at this pit were poorly preserved, the sex could rarely be estimated. The young adult (‘VI’) dated within this study had a similar diet and health as the rest of individuals found at this site ([Jovanović 2017](#)). The isotopic values

³ It belongs to young adult, 20–30 years old.

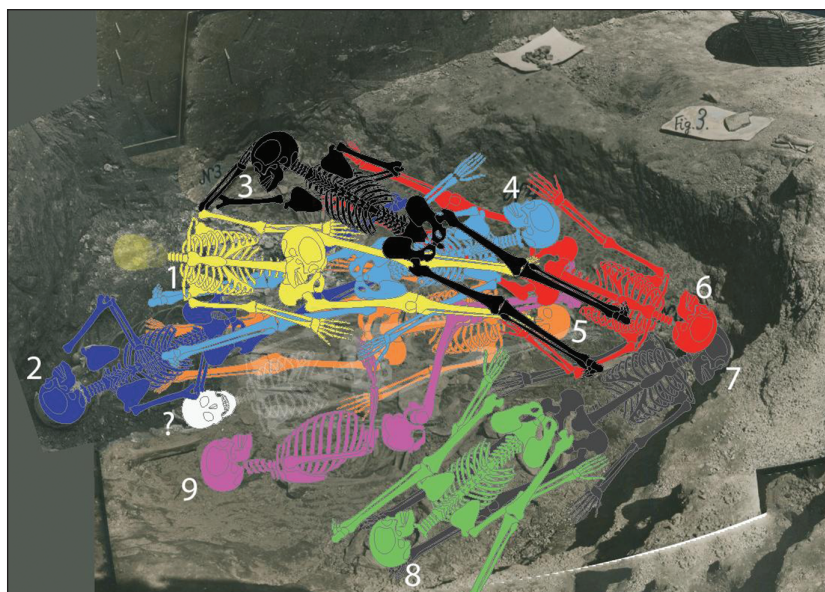


Fig. 4. Ideal reconstruction of the individual positions of Early Neolithic burials on Vinča Belo – Brdo site (reconstruction made by S. Živanović).

$\delta^{13}\text{C}$, $\delta^{15}\text{N}$ and $\delta^{34}\text{S}$ (Fig. 2) show a mostly terrestrial diet (C_3 plants and meat of herbivores and omnivores) with small input of aquatic resources (Nehlich et al. 2010; Jovanović et al. 2018). Although aquatic foodstuff represents a small part of the diet of these individuals, the isotopic ratios show that they had a diet much more abundant in aquatic protein than the inhabitants of contemporary settlements (excluding the Danube Gorges). This could be connected to the fact that site was located very close to the Danube, like sites in the Danube Gorges, where fish was a staple food during the whole Mesolithic – Neolithic sequence, and thus enabled easier access to fish and other aquatic resources (Jovanović et al. 2018). Concerning the health parameters of those individuals, it is interesting to note the relatively low presence of caries compared to contemporaneous individuals in the region (excluding the Danube Gorges, Jovanović 2017). Since all individuals had similar diets, with larger contributions of aquatic resources than other Starčevo individuals, the presence of supragingival calculus may have resulted from the protein diet. This kind of diet coupled with the presence of calculus may have inhibited bacterial activity (Powel 1985), and influenced the lower incidence of caries, such as the case within the Danube Gorges, especially during the Mesolithic sequence (Jovanović 2017). The presence of pit and LEH indicate almost half of them experienced some physiological stress event between 2 and 10 years of age, some of them with multiple episodes, showing their childhoods were not easy and that they probably suffered some nutritional imbalance

or had poor living conditions. This is also confirmed by the presence of CO and PH, with healed or both healed and active lesions at the time of death (Jovanović 2017). The largest number of healed lesions suggest that those individuals successfully coped with a nutritional imbalance or some disease which could have caused these lesions. It is also possible that the cases of PH with mixed reactions, at least in individuals VI and VIII, could be a consequence of the recent violence detected on them. The average height of these individuals was 161cm (Schwidetzky 1971–1972; Mikić 1988), which is the average stature

of Early Neolithic individuals in the region (Jovanović 2017).

Zmajevac

The remains of at least four poorly preserved individuals (two children and two adults) have been discovered at Zmajevac (see SM 2). Only the remains of one individual who is the best preserved among them (marked as Individual 1) have been dated. The dated skull fragment gave a quite early Starčevo date (6204–6011 cal BC, within the 95% CI; SM 4; Tab. 8 in SM 5), which confirmed the relative chronology attribution made by the excavators. The remains belonged to a child, aged 10–11 years (see SM 3). Stable isotope values of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ (Fig. 2) indicate a mostly terrestrial diet based on the consumption of C_3 plants, meat of domesticates and wild game, and/or possibly dairy products, as most of the Early Neolithic children in this region had (Whittle et al. 2002; Jovanović 2017). Traces of supragingival calculus in low amounts were noted on some teeth, which is probably related to diet, oral hygiene, or genetics. While the observed second degree of teeth abrasion is expected on deciduous teeth, it is quite uncommon on the permanent teeth at this age and may indicate that this child consumed very abrasive food (e.g., ground cereals which contained milling stone residue). During early childhood, it experienced some physiological stress event, evidenced by the presence of LEH. The childhood of this individual was not easy, as also witnessed by the presence of an active lesion of CO, indicating that the child was suffering from some nonspecific

stress until death, caused by anaemia, nutritional deficiency or poor living conditions. Possible traces of infection present on the frontal bone, coupled with CO, could have eventually led to the death of this child. The child also had pronounced *m. deltoideus* on the humerus, which could indicate that it was performing some intense physical activity. The second individual from this site is represented only by one bone, belonging to a child between 5 and 10 years of age. The third individual is an adult, more than 20 years old. Since only a few bones are preserved, a more precise age could not be established. However, atrophy of *m. gluteus maximus* could indicate older age of this individual. Curved *linea aspera*, depression on femur and strong platimery (see [SM 3](#)) indicate that this individual probably had constant biomechanical pressure, likely due to the specific position of the legs while performing some activity. The flattened diaphysis of right humerus and pronounced *m. teres major* and *m. latissimus dorsi* lend weight to the argument of the specific position and activity of this individual. Since only a few bones are preserved, detailed reconstruction of the activity patterns of this individual could not be done. The fourth individual is represented only by one tibia, which indicates adult age, more than 20 years.

Rudnik – Kosovski

Although four burials have been discovered at this site, only one is preserved and dated (Burial 1). The date places this individual in the first half of the Starčevo culture sequence (6325–6088 cal BC within the 95% CI; [SM 4](#); Tab. 9 in [SM 5](#)). Considering its geographical position – the southernmost part of the central Balkans, combined with a date that indicates the very beginning of the Starčevo culture, this find could be considered as one more evidence for the assumed south to north direction of the spread of the Neolithic through this territory ([Whittle et al. 2002](#)). The remains belonged to a female, more than 50 years old, whose skull is the only preserved part of the skeleton ([Jovanović 2017](#)). The woman lost two teeth during her life, which probably happened due to caries detected on several teeth ([Jovanović 2017](#)). The strong presence of caries can be connected to her terrestrial diet (mostly based on C₃ plants and meat/dairy products of domesticates and wild game), as indicated by stable isotope ratios of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ ([Jovanović et al. 2018](#)). Both supragingival and subgingival calculus of degrees 1 and 2 were detected on her teeth, which could be a consequence of diet, age, and poor oral hygiene. Barely discernible PH was detected on parietal and occipital bones, with healed lesions ([Jovanović 2017](#)).

Danube Gorges sites

Unlike other regions in this study, that of the Danube Gorges has been extensively explored within the framework of different archaeological and bioarchaeological studies (e.g., [Srejšević 1969](#); [Jovanović 1969](#); [Bonsall et al. 1997](#); [Roksandić 2000](#); [Stefanović, Borić 2008](#); [Borić, Dimitrijević 2009](#); [Stefanović 2012](#); [2016](#); [Borić, Price 2013](#); [Bonsall et al. 2015a](#); [2015b](#); [Filipović et al. 2017](#); [Živaljević et al. 2017](#); [Jovanović et al. 2018](#); [2021](#); [de Becdelièvre 2020](#); [de Becdelièvre et al. 2020](#)). Those studies yielded *inter alia* a large amount of AMS dates, stable isotope and anthropological data on humans who lived in that micro-region and discussed them comprehensively. Therefore, we will not discuss in detail all the new dated individuals from these sites, but rather just single out those who represent outliers.

From Padina, only two adult individuals from Burials 14 (1) and 18 have been AMS dated within the BIRTH project, and the results (9136–8753 and 8801–8489 cal BC within the 95% CI, respectively; [SM 4](#); Tab. 10 in [SM 5](#)) confirmed their relative chronological attribution, placing them to the Early Mesolithic sequence. Stable isotope data obtained for Individual 14 (1) (Fig. 2; [SM 4](#)) indicates it had a similar diet as other individuals from Padina during the Early Mesolithic, which was mainly based on the mixture of wild game and aquatic resources, especially freshwater fish ([Borić, Price 2013](#); [Nehlich et al. 2010](#); [Jovanović et al. 2018](#)).

From the site of Vlasac, 17 individuals were AMS dated. Almost all individuals were dated to the Late Mesolithic sequence (dates spanning from 7527–6257 cal BC within the 95% CI; n=14, [SM 4](#); Tab. 11 in [SM 5](#)), two to the Early Mesolithic phase (Burial 64a; 7936–7589 cal BC within the 95% CI; and Burial 52; 8167–7603 cal BC within the 95% CI; [SM 4](#); Tab. 11 in [SM 5](#)), which is in accordance with their relative chronological assignment. Only one individual from Burial 26 yielded a Medieval date (889–1012 cal AD at 95% CI; [SM 4](#); Tab. 12 in [SM 5](#)) and thus more detailed discussion is given in [Supplementary Material 6](#) (see [SM 6](#)).

The isotopic ratios of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ (Fig. 2; [SM 4](#)) obtained in this study are in accordance with the data published in other dietary studies, which showed that aquatic resources were important throughout the Mesolithic, but that Late Mesolithic humans started to include more anadromous and potamodromous species of fish in their diets (e.g., [Jovanović et al. 2018](#)).

While in the previous two sites the AMS dates mostly confirmed presumed chronological sequence, at the Lepenski Vir site the 14 new dates obtained within the BIRTH project clarified some long-standing debates about chrono-cultural assignments for some burials, but also gave one unexpected result. The results showed that Burials 20 (9176–8762 cal BC within the 95% CI; [SM 4](#); Tab. 13 in [SM 5](#)) and 105 (7708–7519 cal BC within the 95% CI, [SM 4](#); Tab. 13 in [SM 5](#)) are dated to the Early Mesolithic sequence, which is quite surprising for Burial 20, since it was previously associated with the Early Middle Neolithic phase. The individual buried in this grave was a gracile female of non-local origin (*Borić, Price 2013*), although during the Mesolithic most of the individuals were locals. She was buried in a flexed position not typical for Mesolithic burial practice, since individuals were usually buried in extended supine or seated positions (*Borić 2015; Stefanović 2016*). Therefore, she represents the first individual buried in a typical Early Neolithic position during the Mesolithic sequence in this region if a measurement error in the date is to be excluded. Her stable isotope ratios ($\delta^{13}\text{C}$ -19.6, $\delta^{15}\text{N}$ 14.6; *Jovanović et al. 2018*) are indicative for both Mesolithic and Neolithic periods at this site, since a protein diet based on aquatic resources was the staple food throughout the sequence, although in the Transformational/Early Neolithic⁴ and Early Middle Neolithic phases in the Danube Gorges some individuals consumed fewer aquatic resources and favoured more terrestrial products (C_3 plants and meat of herbivores), which is not the case with this woman. For Burial 105, the precise chronological distribution did not exist, and the AMS date placed the remains to the Early Mesolithic phase.

Regarding other burials from this site dated within the BIRTH project, for three of them (Burials 11, 91, 98) the dates are in accordance with their chronological assignment (Transformational/Early Neolithic phase; [SM 4](#)), while for Burials 16, 27a, 27d, 57, and 93 it was not certain in some previous studies (*e.g., Borić, Price 2013; Stefanović 2016*) whether they were associated with this phase. The obtained AMS dates (see [SM 4](#); Tab. 13 in [SM 5](#)) confirmed they also belong to the Transformational/Early Neolithic phase. The relative chronological distribution related to the Early/Middle Neolithic phase of Burials 39, 66, 83a was also questioned in the published stud-

ies (*Borić, Price 2013; Stefanović 2016*), although newly acquired dates (see [SM 4](#)) confirmed they belong to this phase, except for the Burial 39 (see [SM 4](#)), which is associated with the Transformational/Early Neolithic phase.

Their isotopic values (Fig. 2; [SM 4](#)) are in accordance with the dietary patterns, which as aforementioned were related to the broadening of the dietary spectrum toward terrestrial food resources at the onset of the Neolithic in the Danube Gorges for some individuals (*e.g., Burials 39, 57, 83a, 93*). This light shift is connected with the arrival of migrants and contacts between local hunter gatherers and the first agro-pastoralists, who probably brought new food-stuff and dietary habits to the Danube Gorges (*Borić, Price 2013; de Becdelièvre et al. 2020*). The skeleton from Burial 98 has low $\delta^{13}\text{C}$ (-18.1) and the highest value of $\delta^{15}\text{N}$ (18.0) (Fig. 2; [SM 4](#)) among this group of individuals because it belonged to a neonate. As it is supposed that isotopic ratios of children reflect the mother's diet during pregnancy (see the section on Amzabegovo), and the newborns at Lepenski Vir in general exhibit $\delta^{13}\text{C}$ in the range of values recorded for the females, while $\delta^{15}\text{N}$ values are higher (*Grupe et al. 2003; Borić et al. 2004*). Those higher ratios indicate that diet was not the only factor which influenced $\delta^{15}\text{N}$ values, and that other factors such as physiological processes or pathological conditions should also be considered when interpreting this data (*Fuller et al. 2005; Neuberger et al. 2013; Reitsema 2013; Robertson et al. 2014*). This neonate was one of the 40 neonates buried mainly underneath the rear of trapezoidal buildings at Lepenski Vir (*Borić, Stefanović 2004; Stefanović, Borić 2008*). The practice of burying young children underneath the floors is common among Neolithic communities across Anatolia and the Balkans (*Bachvarov 2008*), and was also attested in the nearby site of Vlasac during the Late Mesolithic. Sofija Stefanović and Dušan Borić (2004; 2008) argue that the neonates were interred into burial pits cut through the floor and not sacrificially deposited before the floor was furnished, as was proposed in some studies (*Srejović 1969; Radovanović 2000*). They also highlight that the houses may have a protective role and that ritual reveals a pronounced concern of the community for the death of babies and changes in the perception of the newborns by the members of this society.

⁴ Stratigraphically and chronologically, the Mesolithic and Neolithic sequence in the Danube Gorges is divided into the Early Mesolithic (~9500–7400 cal BC); the Late Mesolithic (~7400–6300 cal BC); the Transformational/Early Neolithic (~6200–5900 cal BC); and the Early/Middle Neolithic (~5900–5500 cal BC) (see [SM 2](#)).

Overall, the health status of all newly dated individuals is in accordance with general picture which suggest relatively good health status of Mesolithic – Neolithic inhabitants over time (*Nemeskéri, Lengyel 1978; y'Edynak 1978; Borić et al. 2014; Stefanović 2012; 2016; Jovanović 2017*), with the exception of treponemal infections, which occur as a major pathological condition in all periods (*Stefanović 2012*). Anthropological studies in Europe showed that with the onset of Neolithic many more individuals had some kind of growth disruption as a consequence of the new lifestyle and poor diet, while in the Mesolithic only a small number of individuals had traces of bad health (*Papathanasiou 2011; Jarošova, Dočkalova 2008; Wittwer-Backofen, Tomo 2008; Jovanović 2017*). However, there is a slight decrease in health in the Neolithic Danube Gorges (*Borić et al. 2014; Stefanović 2016; Jovanović 2017*), which was not as dramatic as that documented in other Early Neolithic populations in Europe, including those in the nearby regions. Although the number of non-healed lesions is slightly higher in the Neolithic sequence, the distribution of nonspecific stress indicators is similar in both periods, which indicates stability in health over time (*Jovanović 2017*). Higher rates of PH are noted for both periods, which could be potentially connected to infectious disease (*Stefanović 2016; Jovanović 2017*). The general stability in health may have been the consequence of a protein rich diet, especially one based on aquatic resources. At the onset of the Neolithic some humans started to have a more terrestrially oriented diet, which caused few cases of caries, but the frequency was still very low comparing with the rates of the communities who lived outside of this region during the Early Neolithic (*Jovanović 2017*). Additionally, although the rates of enamel hypoplasia are similar throughout the sequence, there is however a higher number of stress episodes in the Neolithic, which can possibly be related to new dietary strategies (*Jovanović 2017*).

Southwestern Carpathian Basin

Starčevo – Grad

Several burials have been discovered at this site (see [SM 2](#)) and two of them were previously dated (*Whittle et al. 2002*). The remains of two individuals interred in Burial 1, found during the most recent excavations in 2000s, were AMS dated within the BIRTH project. Both belong to the second half of the Starčevo culture sequence (5638–5545 cal BC, and 5661–5559 cal BC within the 95% CI: [SM 4](#); Tab. 14 in [SM 5](#)). The first skeleton belonged to a female, 55–60 years old (marked as Skeleton 1, *Jovanović 2017*),

buried in a flexed position. At the distance of 0.6m northeast from the Skeleton 1, on the same level, the remains of a child, aged 5–7 years (*Jovanović 2017*) were detected and marked as Skeleton 2. The mean difference between median and mean values of the calibrated dates for these two individuals is 23 years, which could indicate that they were buried together intentionally, but probably not as a part of the single burial event. However, it could also indicate that same burial place was reused, as in the case of some other Starčevo burials, such as Burial 2 at Jaričište 1 (*Stefanović, Porčić 2015*).

Beside these two individuals, in another trench, within the excavation layer, a diaphysis of a left femur with traces of injury probably caused by sharp edge tool (*Jovanović 2017*) has been discovered in a pit associated with the Starčevo culture. Possible traces of injury or palliative treatment were also noticed on a female's occipital bone from Burial 1 (*O.c.*), and presence of a higher degree of PH with mixed healed and active lesions could be the consequence of the same trauma. OA was detected in all preserved vertebrae (*O.c.*), which is in accordance with the woman's old age. The woman experienced several episodes of physiological stress (*e.g.*, nutritional imbalance, high fever, *etc.*) during her childhood, as evidenced by traces of LEH (*O.c.*). She lost two teeth during her life, which is expected due to her old age, while the appearance of both mostly moderately pronounced supragingival and subgingival calculus, especially the large amount on the side of the jaw where she lost teeth ante-mortem, could be connected to some tooth pathology and poor oral hygiene, rather than diet (*O.c.*). Her isotopic values of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ (Fig. 2) indicate she had a mostly terrestrial diet (based on the consumption of C_3 plants and meat/dairy products of domesticates and wild game), as did a child (Fig. 2) buried in the same pit. This is in accordance with archaeozoological (predominance of domesticates, but also a significant contribution of wild animals; *Clason 1980*), previous stable isotope analyses (*Whittle et al. 2002*) and organic residue analysis of pottery with traces of dairy products (*Stojanovski et al. 2020*) from this site.

Topole – Bač

Three prehistoric burials found at this site have been AMS dated within the BIRTH project (*Stefanović et al. 2020*). The new dates solved the almost 20-year mystery of whether Burials 1 and 2 represent one single event or not. Alasdair Whittle and colleagues (*2002*) had some doubts regarding the dating of those two burials, as well as Jovanović and collea-

gues (2017) who concluded that Burials 1 and 2 were almost certainly buried at the same time, and that because of terrestrial dietary patterns they should rather present a single Early Neolithic burial, rather than Mesolithic and Neolithic as the first AMS dating by Whittle and colleagues (2002) showed. The new BIRTH dates confirmed that Individuals 1 and 2 were buried at the same time, since calibrated dates almost completely overlap (for Individual 1, the 95% CI span is 6065–5985 cal BC, while for the Individual 2, the 95% CI span is 6066–5986 cal BC; [SM 4](#); Tab. 15 in [SM 5](#)), and both belong to the Early Neolithic Starčevo culture. New BIRTH stable isotope values (see [SM 4](#)) also showed that this young female (Burial 1) and middle-aged male (Burial 2) had similar, mostly terrestrial diets, like their counterparts from the region (Whittle et al. 2002; Nehlich et al. 2010; Jovanović et al. 2018). While almost the same isotopic ratios were obtained for the male (similar skeletal elements, *i.e.* hand bones, were analysed both times), the new and old $\delta^{15}\text{N}$ ratios slightly differ in female. Namely, the old $\delta^{15}\text{N}$ value is 8.6‰ (Whittle et al. 2002 sampled rib), while the new $\delta^{15}\text{N}$ value is higher, 9.6‰ (in our study the frontal bone was sampled). These variations could be a consequence of sampling different skeletal elements⁵ or due to different laboratory procedures, since the samples were dated in different laboratories.

Both individuals had relatively good health status. The female experienced some stressful event during childhood, as evidenced by traces of LEH, and small traces of supragingival calculus. She was 163.84cm tall (Jovanović et al. 2017), which is more than the average female height during the Early Neolithic (*O.c.*). The male also had a small amount of supragingival calculus. He was 171.32cm tall (Jovanović et al. 2017), taller than most other males from the Early Neolithic (Jovanović 2017; *this study*). His weight was 64.06kg, which is slightly higher than that of his counterparts, while the body mass index, as a general indicator of health, showed that he had a normal body mass index (Jovanović et al. 2017).

The third individual buried several metres away from the first two was also mostly placed beneath the floor of the same structure. It was a young female, dated to the later, Early Bronze Age period

(2873–2628 cal BC within the 95% CI; [SM 4](#); Tab. 16 in [SM 5](#)), although it was previously assumed that it could be older than Burials 1 and 2 (Jovanović et al. 2017), which indicates the disturbance of the Starčevo culture layers in the later periods. This result reveals the possibility that this area was continuously used for living and burial practices. Stable isotope analysis (Fig. 2; [SM 4](#)) showed she had a diet predominantly based on terrestrial resources (C_3 plants, meat/dairy products of domesticates and wild game). Anthropological analysis revealed that she was 168.83cm tall, while her weight was 66.66kg, with a normal body mass index (*O.c.*). The ellipsoid lesion with horizontal lines noted on the frontal bone could be the result of an infection or blunt force trauma (*O.c.*).

Klisa

At this site five Neolithic burials have been found (see [SM 2](#)), but only three individuals which are preserved today and interred in Burials 6, 8 and 10a were AMS dated. The dates have quite close spans, with the Burial 6 being slightly older (5984–5845 cal BC within the 95% CI; Tab. 17 in [SM 5](#)) than the Burial 10a (5978–5780 cal BC within the 95% CI; Tab. 17 in [SM 5](#)), while the Burial 8 appears to be the oldest (6002–5886 cal BC within the 95% CI; Tab. 17 in [SM 5](#)) (see [SM 4](#)). Anthropological analysis showed that the remains of these three individuals belong to a 4 to 5-year old child (Burial 6), a female aged 15–18 (Burial 8) and a male (Burial 10a), who was aged more than 40 at death (Jovanović 2017). Isotopic values of $\delta^{13}\text{C}$, $\delta^{15}\text{N}$ and $\delta^{34}\text{S}$ for the female and male indicate they favoured the consumption of terrestrial proteins (C_3 plants, domestic animals and hunted game), with small input of aquatic resources (Jovanović et al. 2018). One vertebrae of catfish was found during the anthropological analysis, which is rare in the archaeological record from the Starčevo sites outside of the Danube Gorges (Živaljević, Stefanović 2016; Živaljević 2017). The child was possibly breastfed until ~2 years of age, while the increased $\delta^{15}\text{N}$ value just prior to the child's death, was possibly a consequence of disease or nutritional stress (Jovanović 2017). Both child and female had LEH, which indicates they experienced some nonspecific stressful event during childhood. Supragingival calculus is moderately pronounced on several of the female's teeth (*O.c.*), which could be

5 The frontal bone with more cortical tissue renews slower than the rib, and thus the stable isotope ratios should mainly reflect a dietary signal formed over a more extended period than in the case of a rapidly renewed tissue (such as rib). Hence, it is possible that this female consumed fewer protein resources at the end of her life (lower $\delta^{15}\text{N}$ value; rib sample, Whittle et al. 2002) than earlier (higher $\delta^{15}\text{N}$ value; *this study*, [SM 4](#)). For a more detailed discussion see Ivana Živaljević et al. 2021.

due to genetic factors or poor oral hygiene. The male had barely discernible PH, which was healed at the time of death (*O.c.*). Noted OA on some vertebrae (*O.c.*) could be the consequence of physical activity and degenerative changes, which is possible considering the age of this male. He was one of the few males from this time period living outside of the Danube Gorges region for whom the stature could be calculated (170.58cm) (*O.c.*).

Sremski Karlovci – Sonje Marinković 1

The only known Neolithic burial (Burial 1) from this site has been AMS dated and yielded an early Starčevo date (6210–6027 cal BC within the 95% CI; [SM 4](#); Tab. 18 in [SM 5](#)). Anthropological analysis showed that this burial belongs to a female individual, aged 35–50 years old (Jovanović 2017). She had moderately pronounced forms of both types of dental calculus as a consequence of diet (supragingival) and tooth pathology (subgingival). Her isotopic values of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ indicate she had a diet mostly based on terrestrial proteins (such as C_3 plants, domestic animals and hunted game), but also with some input from aquatic proteins (Jovanović et al. 2018). She had the 2nd and 3rd degree of PH which was active at the time of death (*O.c.*). OA changes were noted on the sternum, foramen magnum, scapula, and cervical vertebrae (Jovanović 2017), which in this case may have developed as a consequence of injury, since in the inferior part of the sternum, there is a curvature toward anterior-posterior side. Her stature was 150.37cm, like many females who lived in the region during the Early Neolithic (*O.c.*).

Baštine – Obrež

The skeletal remains of the only known burial from this site (Burial 1) were AMS dated and the obtained date span places this individual in the second half of the Starčevo culture sequence (5624–5517 cal BC within the 95% CI; [SM 4](#); Tab. 19 in [SM 5](#)). It belongs to a child, aged 4–6 years (Jovanović 2017). It had barely discernible CO, healed at the time of death, which suggests that this child successfully coped with some nonspecific stress (*O.c.*). Although this event did not cause the death of the child, it seems that an injury on the left tibia made with some sharp tool, followed by periosteal reaction (*O.c.*), could have been fatal. The isotopic bone values of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ reflect a generally terrestrial dietary pattern which include C_3 plants, domestic animals and hunted game (*O.c.*). However, $\delta^{34}\text{S}$ suggests little input of aquatic food resources, while the abundance of mollusc remains (such are *Helix*, *Unio*, *Vivipara*, *Limnaea* and *Planorbis* genera) (Bruk-

ner 1960a; 1960b) support the sulphur isotopic results. A shallow depression detected behind and along the length of the coronal suture could have arisen if this child was wearing something on the head, connected to everyday habits or cultural traditions (Jovanović 2017).

Bezdan – Bački Monoštor

Three Neolithic burials were found at this site (see [SM 2](#)), and only the remains found in Burial 3 (Fig. 5.a) have been AMS dated. The result (4996–4844 cal BC within the 95% CI; [SM 4](#); Tab. 20 in [SM 5](#)) indicates this individual lived at the beginning of the Late Neolithic. The remains belong to a middle-aged male (see [SM 3](#)), whose $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ ratios (Fig. 2; [SM 4](#)) are consistent with typical Early and Late Neolithic dietary patterns in the region (Whittle et al. 2002; Gamarra et al. 2018; Nehlich et al. 2010; Lightfoot et al. 2011; Jovanović et al. 2018), where the bulk of protein was mostly derived from terrestrial foods based on C_3 plants, domestic animals and hunted game. The man experienced several physiological stress episodes during childhood, as evidenced by traces of pit and LEH, and some of them have happened around the age of 10, indicating he probably grew up in poor living conditions where he suffered from some nutritional deficiency, which is also noted in other two individuals from this site. According to the stature (167.51cm) and body mass (56.66kg), the body mass index was 16.86, indicating he was underweight, which lends weight to the argument for poor living conditions and nutritional deficiency. Noted traces of low to moderate supragingival calculus and periodontitis may be caused also by poor nutrition, or poor oral hygiene/genetics. The presence of grooves with more severe teeth abrasion on the right-side molars indicate he probably processed some type of object in the mouth on the right side of the jaw, which is also supported by greater robustness of the right bones of the upper body. Overall, although muscle attachments are generally not pronounced, they are more marked on the upper limbs. The strong active bilateral periosteal reaction on tibias (Fig. 5.b,c), fibulas and calcanei could be due to bacterial infection. Based on the atrophy of the femur muscles and on the curvature of the tibias it is possible that this man was not mobile. Curvature of the tibias and the platimetry of the femurs could be the result of his specific position due to the low leg mobility. His bones are very gracile which can also be a consequence of pathological condition. Bodies of four cervical vertebrae are recessed, as a consequence of some pressure on the cervical part of the spine, which could also be due



Fig. 5. Bezdan – Bački Monoštor, Burial 3. **a** *in situ*; **b** periosteal reaction on the left tibia; **c** periosteal reaction on the right tibia (a courtesy of the Town Museum of Sombor; b, c photos J. Pendić).

to particular position of the body. On the same vertebrae traces of OA are noted. A benign tumour – osteoma has been detected on the frontal bone. Those kinds of tumours are slow growing and usually cause no symptoms, with men being affected only slightly more than women (Wei, Stevens 2014).

Beside Burial 3, two other undated Burials, 1 and 2, which according to the relative chronology belong to the Late Neolithic, have also been anthropologically analysed (see SM 3). Inside Burial 1 (Fig. 6.a) a middle-aged female was buried in a flexed position. This woman experienced several stress episodes during her childhood, as evidenced by traces of LEH, which occurred between the ages 1.3–3.9 years. Ante-mortem tooth loss is probably due to the presence of caries detected on several teeth (e.g., left mandibular molars; Fig. 6.c), which indicates she perhaps had a diet strongly based on terrestrial resources, especially on carbohydrate rich food. Supragingival calculus was present on multiple teeth in small amounts. She had barely discernible CO and PH with active and healed lesions, indicating she probably lived in poor living conditions where various factors could have led to developing these conditions, such as nutritional deficiency, *etc.* Traces of non-masticatory activities noted on her teeth and unusual dental mandibular arches (Fig. 6.b,c; see SM 3) suggest she used her teeth as a ‘third hand’, which is also confirmed by her muscle attachments which are more pronounced on the upper limbs, especially on the right side. It is possible that this female performed some sort of physical activity since early childhood (see SM 3) that was frequently and continuously repeated, but her muscle attachments do

not indicate any kind of hard physical labour. On the distal ends of both humerus the epigenetic feature perforatio fossa olecrani is noted. Besides the genetic origin (Hauser, de Stefano 1989) this feature can also be a consequence of continuous use of upper limbs in some physical activity (Mays 2008). OA was detected on both hip joint and forearm bones, which in the case of upper limbs can be due to her physical activity. The metopic suture which usually fuses until the age of 8 (Scheuer, Black 2004) is still present in this middle-aged female. Persistence of metopic suture (metopism) in adulthood represents a non-metric anatomical trait (Hauser, de Stefano 1989), which

could have genetic origin (Torgersen 1951; del Sol et al. 1989), although some other factors cannot be excluded (e.g., mechanical causes, hormonal dysfunction, *etc.*). It has little clinical significance, and in some cases can cause problems with frontal sinuses. She was 158.58cm tall (close to average females’ height during the Early and Late Neolithic; Masson 2014; Jovanović 2017; *this study*) and weighed 60.52kg, with a normal body mass index.

Inside the Burial 2, two individuals have been found. Individual 1 represents an old adult, buried in a flexed position (Fig. 7.a), while Individual 2 represents a child, whose remains were poorly preserved (see SM 3). The adult has very similar health as the female from Burial 1, indicating that both probably lived in poor conditions. They also experienced several stress episodes during childhood, as evidenced by traces of LEH, which occurred between the age 2.4–3.9 years, and could be connected (as in the case of woman from Burial 1) to the consumption of solid food (which can be contaminated), or some other nonspecific physiological stress event. In support of this there is healed CO, which also points to some stress event probably occurred during childhood. A large amount of ante-mortem teeth loss is related to the higher presence of caries (Fig. 7.b,c; see SM 3), implying this individual perhaps had a diet strongly based on terrestrial resources, especially on carbohydrate rich food, like the female from Burial 1. The presence of a large amount of supragingival calculus on one carious tooth was probably due to poor oral hygiene. At the moment of death this old adult had PH with mixed lesions, supporting the hypothesis that humans buried at this site pro-

bably lived in poor conditions. Additional porosity detected on other skull bones confirms this individual likely suffered from nutritional deficiency. A circular dent on the parietal bone was most likely caused by blunt force trauma (Fig. 7.d), while traces of bandaging on the lateral borders of the scapulae could be caused by the same event/injury. Overall, the muscle attachments of the upper limbs are more pronounced than on the lower limbs, especially on metacarpal and phalanges which could be the result of some intense physical activity that this adult did with the arms (see SM 3). Although morphological characteristics of the skull bones suggest female sex, the estimation of sex was difficult since there are huge differences in the left and right great sciatic notches and composite arches (Fig. 7.e), where one suggests male and another female sex, respectively (see SM 3). These differences are not due to trauma, since there are no traces of injuries, and rather can be caused by a pathology that did not leave traces on the bones, congenital anomaly, or a specific position in which this adult spent a significant amount of time. Furthermore, visible epiphyseal line on the left femur head, platimery and OA of both femurs head (especially on the left one and on the left acetabulum), could also be a consequence of the presumed specific position of the left leg that the individual adopted during walking, and/or another activity that it did since childhood. However, one cannot exclude that long-term nutritional imbalance during childhood and perhaps the presence of rickets led to slow growth and development, which caused degenerative changes on vertebral bodies, auricular surfaces, and along epiphyseal lines of both femurs. Other OA changes on two thoracic vertebrae and on the sacral promontory probably developed due to old age.

Idoš – Gradište

Only one out of two Neolithic individuals from this site has been dated. The AMS dating places Burial 1 at the very beginning of the Late Neolithic (5213–5027 cal BC within the 95% CI; SM 4; Tab. 21 in SM 5). The remains belonged to a male, aged 30–35 years old. The isotopic ratios of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ (Fig.



Fig. 6. Bezdan – Bački Monoštor, Burial 1. a in situ; b traces of non-masticatory activities on maxillary; c mandibular teeth; on mandibular teeth 36 and 37 the presence of caries is also noted (a courtesy of the Town Museum of Sombor; b, c photos J. Pendić).

2; SM 4) show he had a terrestrial diet based on C_3 plants, domestic animals and hunted game, with possible small input from aquatic resources, like some other Early and Late Neolithic individuals from the region (Whittle et al. 2002; Lightfoot et al. 2011; Nehlich et al. 2010; Gamarra et al. 2018; Jovanović et al. 2018). He had a mild OA and lithic lesions on both glenoid cavities, pronounced muscle attachments on scapulae, clavicles, radius, which coupled with OA changes on all vertebrae and one Schmorl's node, indicate that he intensively used the upper limbs during some physical activity (see SM 3). The appearance of squatting facets indicates this male probably squatted while performing activities with the upper limbs. All bones have dark-brown colour and traces of burning. Since traces of burned wattle and daub have been discovered in Trench 5 (Marić, Pendić 2017), it could be hypothesised that there was maybe a fire at the house roof, which affected buried skeletal remains or, which is less likely, led to suffocation in the fire as a potential cause of death for this male.

The undated human skeletal remains found inside a Late Neolithic pit (see SM 2), in Trench 6 (unit 6007), revealed the remains of two individuals – a female and poorly preserved young adult. The female, aged 45–50 years old, had severe teeth abrasion and periodontitis. On some teeth specific abrasions and grooves were noted indicating that she used her teeth in non-masticatory activities. It is interesting to note that among the inhumated bones, five fragments of cremated human bones were found.

They had traces of white and black colors, which according to Simon Mays (1998) is indicator that the temperature of burning was over 600°C. The presence of transversal cracks suggests that the bones were placed in the fire with the soft tissues still present. It is unclear if these cremated human bones reflect some ritual or mortuary rite, since cremations are rare in the Neolithic (Borić 2015), or this is a consequence of a fire which caused the body to burn completely.

Zmajevo – Livnice

Two Neolithic burials were found at this site (see SM 2). Burial 1, with dislocated remains, belongs to a probable male, aged 30–40 years (see SM 3), whose skeletal remains were poorly preserved and have not been dated. Only the better preserved Burial 2 (Fig. 8.a,b) was dated and yielded a date which spans between 5299–5099 cal BC (within the 95% CI; SM 4; Tab. 22 in SM 5). The date confirms the assumed chronological sequence and places this individual into the Vinča culture. The remains belonged to a male, aged more than 50 years old. The isotopic ratios of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ (Fig 2; SM 4) show he had a diet based on terrestrial proteins derived from C_3 plants, domestic animals and hunted game. OA detected on the upper and lower limbs is in accordance with his old age, and the presence of sharp osteophytes on vertebrae certainly caused pain

to this individual (Fig. 8.c). Active periosteal reaction on the left tibia (Fig. 8.d) (see SM 3), coupled with the presence of initial stages of osteomyelitis on both fibulas, indicate that this was most likely the result of some systemic infection, considering its bilateral presence. Furthermore, lesions and porosity on the inner vault of the skull lend weight to the argument that the infection spread from postcranial skeleton to the whole body. More pronounced muscle attachments on the upper limbs implied he performed some intense physical activity in a specific position leading to the curvature of the forearm bones. Complete loss of teeth (Fig. 8.e) coupled with pronounced muscle attachments on the mandibula could possibly indicate that this male used his teeth in non-masticatory activities. He had a hard life, as evidenced by the presence of healed fractures on a few ribs, and probably after the injury he wore a bind around both scapulae and ribs (see SM 3). Atrophy of the muscle attachments is more present on the lower than upper limbs and can be connected to the presence of sacroiliac fusion, which certainly led to reduced use of the lower limbs and less mobility of this male. Fusion of the sacrum and iliac bones could have been caused by his old age, trauma due to his injury, or arthritic changes. Furthermore, the observed differences between the left (moderately male characteristics) and right (moderately female characteristics; SM 3) great sciatic notch are probably

a consequence of sacroiliac fusion, congenital malformation, or other pathological conditions. The specific position in which this male was buried (lying on his back, hands were placed on the pelvis, with the legs bent at the knees, on the right side; Fig. 8.a), could be due to his illness and reduced mobility of the lower limbs.

Gospodinci – Nove zemlje

The resulting date span places the only individual found at this site (see SM 2) in the first half of the Starčevo culture sequence (6066–5991 cal BC within the 95% CI; SM 4; Tab. 23 in SM 5). This individual is poorly preserved and anthropological information is limited (see SM 3). The sex could not be estimated due to the fragmentation, although a few fragments of cranial bones suggest they could belong to a female. The teeth abrasion indicates that the individual was ~30 years old. Traces of supra-

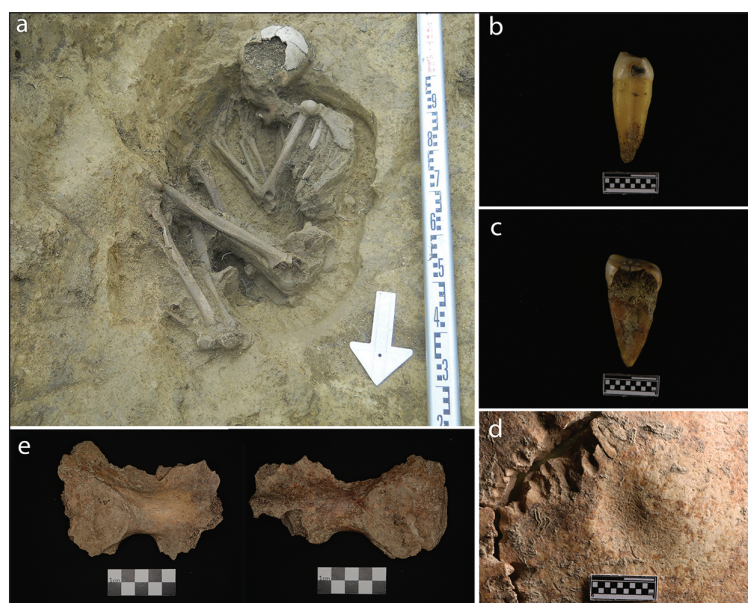


Fig. 7. Bezdan – Bački Monoštor, Burial 2. a in situ; b, c presence of caries on teeth 25 (distal side) and 47 (distal side); d circular dent (10.49 x 8.35mm) on the lower part of the parietal bone, near the juncture of the sagittal and lambdoid suture, most likely caused by a blunt force trauma; e differences in the left and right great sciatic notches and composite arches (a courtesy of the Town Museum of Sombor; b, c, d, e photos J. Pendić).

gingival and subgingival calculus in medium amounts were noted, which is probably related both to the diet and teeth pathology and/or oral hygiene. Stable isotope values of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ (Fig. 2; SM 4) indicate a mostly terrestrial diet based on proteins deriving from C_3 plants, domestic animals and hunted game.

Sajlovo

Only the Neolithic individuals from Sajlovo (see SM 2) have been dated, and the results show that Burial 22 belonged to the second half of the Early Neolithic sequence (5707–5566 cal BC within the 95% CI; SM 4; Tab. 24 in SM 5), while the AMS date (5293–5059 cal BC within the 95% CI; SM 4; Tab. 24 in SM 5) places Burial 19 into the very beginning of the Late Neolithic, although based on pottery findings it was assumed that it also belonged to the Early Neolithic. The previously assumed absence of the Late Neolithic stratum at Sajlovo could be reconsidered, based on the new evidence.

Anthropological analysis revealed that Burial 22 belongs to a child, aged 6–7 years old. The skeleton is poorly preserved and thus anthropological data are limited (see SM 3). The isotopic ratios of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ (Fig. 2; SM 4) show it had mainly a terrestrial diet based on C_3 plants, domestic animals and hunted game. Besides the vicinity of the Danube River (c. 4km) and the fact that one vertebra of carp was found during anthropological analysis, its isotopic data indicate that aquatic resources were rarely used. The child experienced nonspecific physiological stress several times during childhood, as evidenced by traces of pit and LEH. One of those stress events occurred around the age of 2, which perhaps could be connected to weaning, since this age is inside the time frame when children cease breastfeeding and completely transfer to solid food (e.g., Jovanović et al. 2017), or perhaps was the result of some other stress factor.

Burial 19 (Fig. 9.a) belonged to a female aged 45–50 years (see SM 3). This Late Neolithic woman had



Fig. 8. Zmajev – Livnice, Burial 2. a, b *in situ*; c presence of sharp osteophytes on vertebrae; d active periosteal reaction on the left tibia; e mandible showing complete loss of teeth (a, b courtesy of the Provincial Institute for Protection of Cultural Monuments, Vojvodina; c, d, e photos J. Pendić).

similar physical characteristics, diet, and health status as Early Neolithic individuals. She was 149.13cm tall, which is shorter than the average recorded for the Early Neolithic females (Jovanović 2017). The stable isotopic ratios of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ (Fig. 2; SM 4) show she had mainly a terrestrial diet which included C_3 plants, meat (dairy products?) of domestic animals and hunted game. The presence of caries supports this conclusion, and furthermore indicates the use of food enriched in carbohydrates. The presence of a small to medium amount of supragingival calculus (Fig. 9.b) could be a consequence of poorer oral hygiene, diet and her older age. Her childhood was not easy, as has also been noted for most of the Early Neolithic humans from the region (O.c.). The presence of LEH suggests she also experienced nonspecific physiological stress around the age of 2, like the child from Burial 22. Barely discernible PH, which was healed at the time of death, could also be an indicator of some stress event. This woman may have had limited range of motions due to pain caused by OA, spondylarthrosis, and Schmorl's node on the cervical vertebrae, whose presence is consequence of degenerative changes as a result of her older age. Furthermore, atrophy of muscle attachments on both upper and lower limbs lends weight to this argument.

Highway E-70, 521km

The resulting date span places the only individual available from this site (see [SM 2](#)) in the second half of the Starčevo culture sequence (5616–5486 cal BC within the 95% CI; [SM 4](#); Tab. 25 in [SM 5](#)). Anthropological analysis showed that it was a female, between 30–40 years old (see [SM 3](#)). The presence of caries could be the result of her mostly terrestrial diet (C_3 plants, domestic and wild game) with a possible small input of aquatic resources, as evidenced by stable isotope values of $\delta^{13}C$ and $\delta^{15}N$ (Fig. 2; [SM 4](#)). The pronounced muscle attachments of the upper limbs, egg-shaped humeral head and curvature of both humeral diaphysis (Fig. 10.a) indicate she performed intense physical activity with her upper limbs. The pronounced muscle attachments of her upper limbs in combination with specific abrasion of her front teeth (Fig. 10.b) may indicate that she used her teeth in non-masticatory activities. OA was noted on two lumbar vertebrae, while on one of them there is a shallow depression-Schmorl's node (Fig. 10.c), which could be a consequence of physical work. On the medial side of the right tibia a mild inactive periosteal reaction is noted, which is the result of some nonspecific infection, probably not fatal, because it is localised to only one region of the bone. Both tibias are slightly medially curved, especially the right one, which could be connected to the appearance of periosteal reaction. However, since it was inactive at the time of death it shows that this woman successfully coped with this issue. Analysis revealed she had a lower height (147.43cm) and less weight (46.76kg) than most of the other Early Neolithic females (*Jovanović 2017*), with normal body mass index.

Novi Sad – Gornja šuma

Three possible Neolithic burials (1, 2, 4) from this site (see [SM 2](#)) were dated, and the AMS dates span within the very beginning of the Late Neolithic Vinča culture, with the possibility that individuals from Burials 1 and 4 lived and were buried roughly at the same time (Burial 1: 5296–5066; Burial 2: 5224–5050 and Burial 4: 5291–5058 cal BC within the 95% CI; [SM 4](#); Tab. 26 in [SM 5](#)). The isotopic ratios of $\delta^{13}C$ and $\delta^{15}N$ (Fig. 2; [SM 4](#)) of all individuals have roughly simi-

lar values, indicative of a terrestrial dietary pattern with the inclusion of C_3 plants, domesticates and wild game. Burial 1 belongs to a male, aged 20–25 years old (see [SM 3](#)). Cribra humeri, cribra femori (Fig. 11.a), PH as well as porosity on some of the bones suggest he had some nutritional imbalance, and traces of LEH indicate he probably had some nutritional deficiency since early childhood. Traces of supragingival calculus of degree 1 and periodontitis were also noted in this male, which in this case may also be caused by poor nutrition (*e.g.*, especially deficiency in vitamin C), or other factors. The presence of periostitis on the right radius and tibias may indicate this young male had some systemic infection. Burial 2 belongs to a middle-aged adult (see [SM 3](#)), who suffered from severe OA on ulnas (Fig. 11.b), which could be caused by the possible injury since traces of bandaging were noted on the left radius, whose diaphysis is also slightly enlarged in that area.

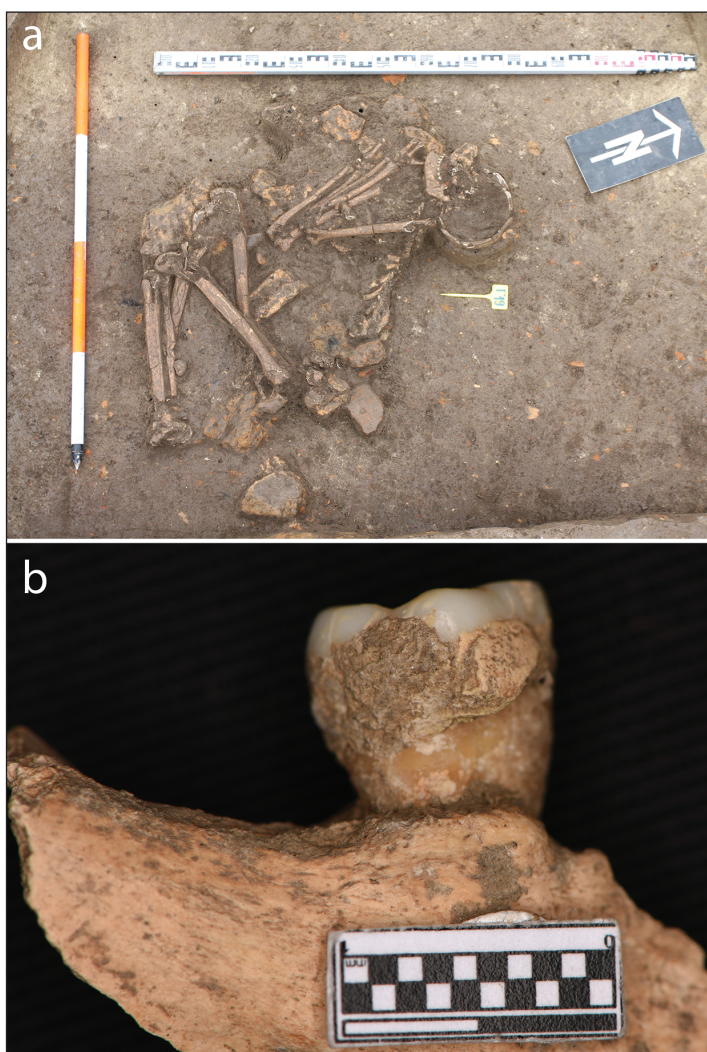


Fig. 9. Sajlovo, Burial 19. a in situ; b presence of supragingival calculus on tooth 48, buccal side (a from Veselinov 2013; b photo J. Pendić).

Active periosteal reaction noted on the inner side of one rib body usually indicates the presence of some lower respiratory tract disease (Davies Barret et al. 2019), while the presence of the same reaction on the right femur could be due to trauma, metabolic disease, or some other factor (Ortner 2003; Waldron 2009). The presence of epiphyseal lines on the right femur and humerus in this middle-aged adult indicate this may have occurred as a consequence of disturbances in growth and development, malnutrition (Johnston, Zimmer 1989), environmental and sociocultural factors (Johnston, Zimmer 1989; Belcastro et al. 2019), or perhaps due to some kind of hard physical labour (Stefanović 2006) that this individual did in childhood. Burial 4 belongs to a child, aged 5–7 years old (see SM 3). The child had a strong presence of nonspecific stress indicators (CO, cribra femoris and PH; Fig. 11.c,d), and a mixture of active and healed lesions suggest it tried to cope with this condition, but unfortunately without success, since it died. It also had other health issues, probably caused by long-term nutritional imbalance. Its pelvis was not developed enough in relation to the rest of the postcranial skeleton, especially in relation to the femurs, which could be the consequence of an irregular osteogenesis process. Furthermore, iliac fossa is almost missing on the iliac bones, suggesting some developmental disorder. Lower limb bones indicate the child had the initial stage of rickets (see SM 3), caused by long-term sitting or lying because of the underdeveloped pelvis. Limited movement and assumed excessive lying in the house could have led to vitamin D deficiency, and consequently the development of the rickets. In support of this there is a small dent on the metatarsal bone, which can be the consequence of some specific position which this individual habitually maintained. Muscle attachments on the upper limbs are too pronounced for a child of this age, which could indicate the child did some intense physical activity or leaned on its hands due to the limited mobility of the lower limbs. Mostly active periosteal reactions were noted on both upper and lower limb bones. Although periosteal formation can result from a variety of etiological factors (e.g., traumas, metabolic, rheumatic, cancer and circulatory disorders and infectious diseases, all summarised in Marques et al. 2018), it is possible that the main cause, in this case, was either rickets or mechanical strains caused by movements.

Beli Manastir – Popova zemlja

Nine burials were AMS dated from this site (see SM 2), and according to the obtained results all burials belong to the Neolithic, whereas most of them are



Fig. 10. Highway E-70 521km, Burial 1. **a** the pronounced muscle attachments and the curvature of the left humeral diaphysis; **b** specific abrasion of the front teeth; **c** shallow depression-Schmorl's node (photo J. Pendić).

dated to the Late Neolithic Sopot culture (4706–4489 cal BC within the 95% CI), corresponding well to the previously dated burials (Mathieson et al. 2018). Three possible clusters of burials, closely related in terms of temporal provenience, can be observed. The first cluster consists of Burials 6 and 3 (4706–4555 cal BC and 4704–4552 cal BC within the 95% CI; SM 4; Tab. 27 in SM 5). Within the second cluster are Burials 2, 4 and 37 (4691–4541 cal BC, 4691–4536 cal BC, 4692–4538 cal BC within the 95% CI; SM 4; Tab. 27 in SM 5). The third cluster consists of Burials 5, 1 and 11 (4687–4526 cal BC, 4681–4495 cal BC, 4681–4489 cal BC within the 95% CI; SM 4; Tab. 27 in SM 5). Only Burial 16 (5882–5741 cal BC within the 95% CI; SM 4; Tab. 27 in SM 5), was dated to the Early Neolithic Starčevo culture, which is also in accordance with another Starčevo culture date from this site (O.c.). All dated individuals belong to children aged 2–15 years old, except one, Burial 3 (Fig. 12.a), where an old female was interred. They were all buried in a typical Neolithic flexed position (e.g., Fig. 12.b; see also SM 3).

Anthropological analyses showed that the most of individuals buried at this site had poor health status, visible through presence of CO, PH, and periostitis (see SM 3). Although in all cases lesions were healed, they are however indicative of hard childhood and nutritional imbalance of these individuals. The bilateral presence of periostitis on the tibias of the children interred in Burials 4 and 5 could

possibly indicate to some systemic infection. Besides children, healed periostitis is present in old woman (Burial 3), on femurs, left fibula, and the right tibia, coupled with osteomyelitis on the left tibia. Since these nonspecific infection indicators are bilaterally present, it is also likely that she had some systemic infection. This woman had a hard life, which is evident by the presence of degenerative OA on both hips and osteophytosis on multiple vertebrae, which probably caused pain and limited mobility of the spine. Analysis revealed she was 151.75cm tall, which is the average height of Late Neolithic females in the region (Masson 2014; *this study*). The woman also had caries and ante-mortem tooth loss, which she perhaps lost because of the presence of caries. The appearance of caries seems to be common in Late Neolithic humans from the region (Masson 2014; *this study*), and could be due to a mainly terrestrial diet, enriched in carbohydrates. The stable isotopic ratios (Fig. 2; SM 4) of these individuals range from -19.8‰ to -19.2‰ ($\Delta=0.8\text{‰}$; $n=7$) for carbon and 7.7‰ to 11.8‰ ($\Delta=4.1\text{‰}$; $n=7$) for nitrogen, and are consistent with typical Early and Late Neolithic dietary patterns in the region (Whittle et al. 2002; Nehlich et al. 2010; Lightfoot et al. 2011; Gamarra et al. 2018; Jovanović et al. 2018), showing that they consumed terrestrial resources (C_3 plants, domesticates and wild game) with no isotopic evidence for the use of aquatic food. The only exception from this site is a child interred in Burial 6 whose $\delta^{15}N$ value (11.8‰) is higher than others who have below 9.5‰ , but this is probably due to the young age of this child and can be related to the effects of breast-

feeding or some other physiological factor. Possible traces of trauma are detected in a child interred in Burial 2, visible through the presence of some ante-mortem tooth loss.

Vukovar – Gimnazija

Five burials were found at this site (see SM 2), and only one, Burial 3 has been AMS dated. The result (3361–3104 cal BC within the 95% CI; SM 4; Tab. 28 in SM 5) shows it belonged to the Eneolithic, probably Baden culture, although it was previously presumed that it belonged to the Early Neolithic. In the light of this new date and since all other burials are found at the same level, although archaeological data are modest one can assume that they also belong to the Eneolithic as well. The dated skeleton belongs to a child ~10 years old, whose stable isotope values show a terrestrial diet, as seen in other individuals buried at this site (Lightfoot et al. 2011). A diet based on terrestrial C_3 plant resources, domesticates and wild game seems to be common from the Early Neolithic to the Eneolithic in the Carpathian basin (Giblin 2011; Lightfoot et al. 2011; Gamarra et al. 2018; Jovanović et al. 2018), apart from individuals found at the mass burial site of Potočani whose diet was more enriched in terrestrial proteins, such as meat and dairy products, than elsewhere (McClure et al. 2020). The child experienced some nonspecific physiological stress, evident in the presence of LEH and CO, common stress indicators in Early and Late Neolithic communities in this region (Masson 2014; Jovanović 2017). Although at the moment of death the CO lesions were healed, it seems that some other unknown factors led to the child's death.



Fig. 11. Novi Sad – Gornja šuma; Burial 1. a Cribra femori on the left femur; b Burial 2: Osteoarthritis on the right ulna; c Burial 4; Cribra orbitalia on the left orbital roof; d Porotic hyperostosis on the skull bones (photo J. Pendić).

Vinkovci Ervenica – Poljski jarak

The only dated burials from this site are Burials 2 and 3 (see SM 2), which confirmed their assumed Early Neolithic culture attribution (5777–5664 and 5731–5646 cal BC within the 95% CI, respectively; SM 4; Tab. 29 in SM 5). Two old females (>50 years old) were found inside them. According to the AMS dates it could be argued that these individuals lived roughly at the same time, maybe representing two generations. They both had a very similar terrestrial diet (Fig. 2; SM 4) based mostly on C_3 plants, domesticates and wild game meat, which probably caused higher incidence of caries followed

by abscesses and a large amount of ante-mortem tooth loss. A similar dietary (Whittle et al. 2002; Nehlich et al. 2010; Lightfoot et al. 2011; Gamarra et al. 2018; Jovanović et al. 2018) and oral health (Masson 2014; Jovanović 2017) pattern is seen in other Early Neolithic individuals from the region. Both women had two types of calculus (see SM 3), whose appearance was connected to pathological conditions detected on the teeth and poor oral hygiene rather than diet, especially in woman from Burial 2. They both had some of the non-specific stress indicators which implied a hard childhood and nutritional imbalance. The woman interred in Burial 2 had OA on both hips and several vertebrae, coupled with the presence of Schmorl's nodes and bony ankylosis on both pelvic bones and sacrum, as well as in two lumbar vertebrae. These modifications are probably the result of degenerative changes (or perhaps injury/disease) and were certainly painful and caused restricted mobility of this female. The female from Burial 3 also had OA on the same bones as the woman from Burial 2, as well as on shoulder joints, where one can notice that the right one is more affected than the left, which can be related to the fact that right humerus is shorter than the left one. Regarding stature, the woman from Burial 2 was shorter (149.69cm) than the woman from Burial 3 (157.51cm). However, she was approximately around the average stature for an Early Neolithic female in the region (Jovanović 2017).

Conclusion

This paper presents a comprehensive set of different types of data (the results of anthropological and stable isotope analysis, and the results of radiocarbon dating), obtained on the prehistoric human remains from a vast geographic area. The sample consists of all the available human remains from the Neolithic sites at the territory of southern and central Balkans, and southwestern Carpathian Basin, analysed or re-analysed within the project BIRTH. The results filled in the gaps in some of the older interpretations, but also produced new insights for particular sites regarding different issues – chronology, health and diet, and the interpretation of contexts within the sites. These results are mainly presented in the contexts of the individual sites and discussed as such



Fig. 12. Beli Manastir – Popova zemlja. a Burial 3; b Burial 4, in situ.

within the appropriate temporal and spatial attribution, and to a lesser extent on a regional basis.

New radiocarbon dates obtained on human remains also contributed to the reconstruction of Early Neolithic population dynamics. They were used within a larger sample of dates, and as a separate, control sample, for implementing the *summed calibrated radiocarbon probability distributions* (SCPD) method, which enabled testing the main hypotheses of the Neolithic Demographic Transition (NDT) theory regarding changes in the population dynamics during the Early Neolithic within the territory of the central Balkans and parts of the southwestern Carpathian Basin (Porčić et al. 2021). The results indicate a fast and constant population growth at the beginning of the Early Neolithic, followed by several episodes of a decrease in population size, and then population recovery and new growth (the so-called boom and bust pattern), combined with high growth rates. These results are mostly consistent with the results for other European regions, and also with the predictions of the NDT, even though some local differences and specificities have been observed (*O.c.*).

The distribution of Early Neolithic sites with burials in the south and central Balkans and southwestern Carpathian Basin, albeit insufficiently researched in some areas, reveals some common elements in mortuary practices and the social need for burials. The deceased are found within the settlements and usually buried into pits, underneath the house floor or into sporadic burials scattered across settlements, or within the excavation layer. They are mostly found in typical Neolithic flexed positions. There are also examples of re-using of pits for burial purpose (e.g., at Jaričište and Starčevo – Grad) and the potential

re-burying/relocating of the deceased and secondary manipulation of mandibles at Govrlevo and Tumba – Madžari, which can be due to some ritual deposition. Analysis of mortuary practice also shows existence of collective burial at Vinča – Belo Brdo site, and those kinds of burials are rarely seen in the Early Neolithic and Starčevo culture sites. This site is also unique, since almost all individuals found here bear traces of violence, which are rarely witnessed in other sites in this period. Anthropological analyses of Neolithic burials showed that the remains of children and females were more represented than male ones, while the burials of neonates are usually missing (apart from in the Danube Gorges), which may be due to taphonomic factors (*e.g.*, type of soil, recovery issues, *etc.*). The rest of the age groups are more-or-less evenly distributed between infants to old adults.

Regarding the Late Neolithic, the important findings represent the discovery of more than 15 burials AMS dated to the Late Neolithic. Since they are rarely discovered, every find of the human remains from this period are important, as they can lead to a better understanding of the biological characteristics, mortuary practices and possible social ranking of members of the Vinča and Sopot culture communities. A few existing studies focused on some social aspects and demographic issues (*e.g.*, Zoffman 1987; Stefanović 2006), but rarely on the diet and health of these people (Masson 2014). The discovery of Late Neolithic burials sheds new light on their physical-anthropological characteristics and lifestyle, showing continuity between the Early and Late Neolithic in terms of diet and health.

The stable isotope results showed that most of the Early and Late Neolithic humans, apart from those in the Danube Gorges, consumed a terrestrial diet based on C₃ plants and animal resources, with no isotopic evidence for the usage of aquatic resources. The only exception are a few sites located in close vicinity to the rivers, such as Vinča – Belo Brdo, Sremski Karlovci, Obrež – Baštine, and Klisa, suggesting their inhabitants had a higher intake of aquatic proteins. The proximity of the Danube River was certainly of crucial importance for their aquatic intake, as is the case with the Danube Gorges communities. The Danube Gorges sites had excellent riverine positions where many whirlpools aided in specialised fishing, thus aquatic resources were a staple food throughout the Mesolithic – Neolithic sequence, albeit some individuals shifted their diet toward more terrestrial foodstuff during the Neolithic.

There is also continuity in the health status between Early and Late Neolithic communities, where both show poor health, like most of the contemporary Neolithic communities across Europe.

The study shows these individuals had hard, stressful childhood and unbalanced nutrition (especially those buried at Zmajevac, Vinča – Belo Brdo, Starčevo – Grad, Bezdan – Bački Monoštor, Sajlovo, Novi Sad – Gornja šuma, Vinkovci Ervenica – Poljski jarak). Furthermore, some of them bear traces of intense physical work, such as those found at Zmajevac, Bezdan – Bački Monoštor, Zmajevac – Livnice, Highway E-70, 521km. They also show signs of restricted mobility (*e.g.*, Bezdan – Bački Monoštor, Zmajevac – Livnice, Novi Sad – Gornja šuma, Beli Manastir – Popova zemlja, Vinkovci Ervenica – Poljski jarak) and repeated infections (Zmajevac, Bezdan – Bački Monoštor, Zmajevac – Livnice, Highway E-70, 521km, Novi Sad – Gornja šuma, Beli Manastir – Popova zemlja).

In contrast, the Neolithic humans in the Danube Gorges show no significant decline in health compared to the Mesolithic inhabitants of the same region. The only major health problem through the time were infections. This stability in health over the Mesolithic – Neolithic period may result as a consequence of a food abundant in proteins, especially one based on aquatic resources. In the Neolithic, some humans started to include more terrestrial resources in the diet, which caused few cases of caries, while changes in dietary strategies seems to be related to higher number of stress episodes visible through analysis of enamel hypoplasia. In general, analysis of health status showed that communities in the Danube Gorges seem to have been of better health than the Neolithic groups living in other regions. This marked difference is a result of multiple factors, most prominently the differences in dietary pathways, environmental conditions, cultural habits and, at least for the Danube Gorges, adherence to the Mesolithic traditions. This study has given a detailed and strong baseline for all future research regarding particular questions of interest within different research frameworks concerning the Early and Late Neolithic lifestyles.

ACKNOWLEDGEMENTS

This research is a result of the Project 'BIRTH: Births, mothers and babies: prehistoric fertility in the Balkans between 10 000–5000 BC', funded by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (Grant Agreement No. 640557). M. Novak was additionally supported by the Croatian Science Fund grant HRZZ IP-2016-06-1450. We are grateful to our colleagues from different institutions for their kind help and access to the material: D. Andelić, D. Gačić, L. Balj, A. Putica, V. Uzelac, M. Blagojević, D. Đurđević, N. Šošić, N. Tasić, M. Marić, D. Veselinov, M. Živković. We would also like to thank J. Pendić for the photographs done for this study. The authors would like to thank the reviewers for their valuable comments and suggestions that improve the quality of the paper.

∴

References

- Arcini C. 2009. Losing face. The worldwide phenomenon of ancient prone burial. In I.-M. Back Danielsson, I. Gustin, A. Larsson, N. Myrberg, and S. Theeden (eds.), *Döda personers sällskap Gravmaterialens identiteter och kulturella uttryck. On the threshold Burial Archaeology in the Twenty-first Century*. Stockholm Studies in Archaeology. Stockholm University. Stockholm: 187–202
- Baker S. J., Jacob E., Rajan R. T., and Swaminathan S. P. 1962. Vitamin B12 deficiency in pregnancy and the puerperium. *British Medical Journal* 1: 1658–1661. <https://doi.org/10.1136/bmj.1.5293.1658>
- Belcastro M. G., Pietrobelli A., Rastelli E., Iannuzzi V., Toselli S., and Mariotti V. 2019. Variations in epiphyseal fusion and persistence of the epiphyseal line in the appendicular skeleton of two identified modern (19th–20th c.) adult Portuguese and Italian samples. *American Journal of Physical Anthropology* 169(1): 448–463. <https://doi.org/10.1002/ajpa.23839>
- Bogdanović M. 2004. *Grivac, naselja protostarčevačke i vinčanske culture*. Centar za naučna istraživanja Srpske akademije nauka i umetnosti, Univerziteta u Kragujevcu i Narodni muzej Kragujevac. Kragujevac.
- Bonsall C., Lennon R., McSweeney K., +5 authors, and Chapman J. 1997. Mesolithic and Early Neolithic in the Iron Gates: A palaeodietary perspective. *Journal of European Archaeology* 5(1): 50–92. <https://doi.org/10.1179/096576697800703575>
- Bonsall C., Vasić R., Boroneant A., + 9 authors, and Cook G. 2015a. New AMS ¹⁴C dates for human remains from stone age sites in the Iron Gates reach of the Danube, Southeast Europe. *Radiocarbon* 57(1): 33–46. doi:10.2458/azu_rc.57.18188
- Bonsall C., Cook G., Pickard C., + 6 authors, and Boroneant A. 2015b. Food for Thought: Re-Assessing Mesolithic Diets in the Iron Gates. *Radiocarbon* 57(4): 1–11. https://doi.org/10.2458/azu_rc.57.18440
- Borić D. 1996. Social Dimensions of Mortuary Practices in the Neolithic: A Case Study. *Starinar* 47: 67–83.
2009. Absolute Dating of Metallurgical Innovations in the Vinča Culture of the Balkans. In T. Kienlin, B. Roberts (eds.), *Metals and Societies: Studies in Honour of Barbara S Ottaway*. Dr Rudolf Habelt GmbH. Bonn: 191–245.
2010. Happy forgetting? Remembering and dismembering dead bodies at Vlasac. In D. Borić (ed.), *Archaeology and Memory*. Oxbow Books. Oxford: 48–67.
2011. Adaptations and transformations of the Danube Gorges foragers c. 13,000–5500 cal. BC: an overview. In R. Krauß (ed.), *Beginnings – new research in the appearance of the Neolithic between Northwest Anatolia and the Carpathian Basin*. Verlag Marie Leidorf GmbH. Rahden/Westfalen: 157–203.
2015. Mortuary Practices, Bodies and Persons in the Neolithic and Early– Middle Copper Age of Southeast Europe. In C. Fowler, J. Harding, and D. Hofmann (eds.), *The Oxford Handbook of Neolithic Europe*. Oxford University Press. Oxford: 1–23.
- Borić D., Grupe G., Peters J., and Mikić Ž. 2004. Is the Mesolithic-Neolithic subsistence dichotomy real? New stable isotope evidence from the Danube Gorges. *European Journal of Archaeology* 7(3): 221–248. <https://doi.org/10.1177/1461957104056500>
- Borić D., Stefanović S. 2004. Birth and death: Infant burials from Vlasac and Lepenski Vir. *Antiquity* 78 (301): 526–546. <https://doi.org/10.1017/S0003598X00113201>
- Borić D., Dimitrijević V. 2009. Apsolutna hronologija i stratigrafija Lepenskog Vira. *Starinar* LVII: 9–55. <https://doi.org/10.2298/STA0757009B>
- Borić D., Price T. D. 2013. Strontium isotopes document greater human mobility at the start of the Balkan Neoli-

thic. *Proceedings of the National Academy of Sciences* 110(9): 3298–3303.

<https://doi.org/10.1073/pnas.1211474110>

Borić D., French C. A. I., Stefanović S., +5 authors, and Filipović D. 2014. Late Mesolithic lifeways and deathways at Vlasac (Serbia). *Journal of Field Archaeology* 39(1): 1–31. <https://doi.org/10.1179/0093469013Z.00000000070>

Brukner B. 1960a. Rezultati zaštitnog iskopavanja lokaliteta 'Baštine' kod sela Obreža. Rad Vojvodanskih muzeja 9: 81–111.

1960b. Baštine – Obrež – Srem – Naselje. *Arheološki pregled* 2: 18–24.

Clason A. T. 1980. Padina and Starčevo: game, fish and cattle. *Palaeohistoria* 22: 142–173.

Chapman J. 1983. Meaning and Illusion in the Study of Burial in Balkan Prehistory. In A. G. Poulter (ed.), *Ancient Bulgaria*. Papers presented to the international Symposium on the Ancient History and Archaeology of Bulgaria. University of Nottingham (1981). University of Nottingham. Nottingham: 1–42.

2006. Why was the Vinča-Belo Brdo tell occupied for so long? In B. Vorgić, B. Brukner (eds.), *Current problems of the Transition periods from the Starčevo to the Vinča culture*. Narodni muzej Zrenjanin. Zrenjanin: 213–236.

Davies-Barrett A. M., Antoine D., and Roberts C. A. 2019. Inflammatory periosteal reaction on ribs associated with lower respiratory tract disease: A method for recording prevalence from sites with differing preservation. *American Journal of Physical Anthropology* 168(3): 530–542. <https://doi.org/10.1002/ajpa.23769>

Del Sol M., Binignat O., Bolini P. D. A., and Prates J. C. 1989. Metopismo no individuo Brasileiro. *Revista Paulista de Medicina* 107(2): 105–107.

de Becdelièvre C. 2020. *Eco-ethology of prehistoric populations living in the Danube Gorges c. 9500–5500 BC. Bioarchaeological perspectives on human habitual behavior and adaptive strategies during the Mesolithic and Neolithic transformations*. Unpublished PhD thesis. Faculty of Philosophy. University of Beograd. Beograd.

de Becdelièvre C., Jovanović J., Goude G., Le Roy M., Rotier S., and Stefanović S. 2015. Prehistoric Motherhood: diet from the pregnancy stage to the process of baby weaning in the Mesolithic-Neolithic Danube Gorges (Balkans, 9500–5500BC). *American Journal of Physical Anthropology* 156: 116. <https://doi.org/10.1002/ajpa.22716>

de Becdelièvre C., Jovanović J., Hofmanová Z., Goude G., and Stefanović S. 2020. Direct insight into dietary adaptations and the individual experience of Neolithisation: comparing subsistence, provenance and ancestry of Early Neolithic humans from the Danube Gorges c. 6200–5500 cal BC. In K. J. Gron, L. Sørensen, and P. Rowley-Conwy (eds.), *Farmers at the Frontier. A Pan – European Perspective on Neolithisation*. Oxbow Books. Oxford, Philadelphia: 45–75.

Fidanoski L. 2013. Review of the archaeological researches of the Neolithic Settlement of Cerje-Govrevo. *Cultural and historic heritage of the R. Macedonia LXII*: 7–24.

2019. The Beginning of the End: the Story of the Neolithisation of North Macedonia. *Eurasian Prehistory* 15 (1–2): 163–212. <https://epub.oeaw.ac.at/0xc1aa5576%200x003c2e4a.pdf>

Filipović D., Jovanović J., and Rančić D. 2017. In search of plants in the diet of Mesolithic-Neolithic communities in the Iron Gates. In M. Mărgărit, A. Boroneanț (eds.), *From hunter-gatherers to farmers: human adaptations at the end of the Pleistocene and the first part of the Holocene: papers in honour of Clive Bonsall*. Editura Ceta-tea de Scaun. Targoviște: 93–111.

Fuller B. T., Fuller J. L., Sage N. E., Harris D. A., O'Connell T. C., and Hedges R. E. M. 2005. Nitrogen balance and $\delta^{15}\text{N}$: why you're not what you eat during nutritional stress. *Rapid Communications in Mass Spectrometry* 19 (19): 2497–2506. <https://doi.org/10.1002/rcm.2090>

Fuller B. T., Fuller J. L., Harris D. A., and Hedges R. E. M. 2006. Detection of breastfeeding and weaning in modern human infants with carbon and nitrogen stable isotope ratios. *American Journal of Physical Anthropology* 129: 279–293. <https://doi.org/10.1002/ajpa.20249>

Gamarra B., Howcroft R., McCall A., + 11 authors, and Pinhasi R. 2018. 5000 years of dietary variations of prehistoric farmers in the Great Hungarian Plain. *PLoS ONE* 13(5): e0197214. <https://doi.org/10.1371/journal.pone.0197214>

Giblin J. I. 2011. *Isotope Analysis on the Great Hungarian Plain: An Exploration of Mobility and Subsistence Strategies from the Neolithic to the Copper Age*. Unpublished PhD thesis. Department of Anthropology. The Ohio State University. Columbus.

Grbić M. 1934. Neolitsko groblje u Botošu kod Vel. Bečke-reka. *Starinar* 8–9: 40–58.

Grupe G., Peters J., and Mikić Ž. 2003. The exploitation of freshwater food resources by Meso – and Neolithic populations of Central Europe. In G. Burenhult, S. Westergaard

(eds.), *Stones and bones: formal disposal of the dead in Atlantic Europe during the Mesolithic-Neolithic interface 6000–3000 BC*. Archaeopress. Oxford: 177–187.

Hauser G., De Stefano G. F. 1989. *Epigenetic variants of the human skull*. Schweizerbart. Stuttgart.

Ivkovska A. 2009. Animal Husbandry and Hunting. In G. Naumov, Lj. Fidanoski, I. Tolevski, and A. Ivkovska (eds.), *Neolithic Communities in the Republic of Macedonia*. Dante. Skopje: 53–63.

Jarošova I., Dočkalova M. 2008. Dental remains from the Neolithic settlements in Moravia, Czech Republic. *Anthropologie* 46(1): 77–101.

Johnston F. E., Zimmer L. O. 1989. Assessment of growth and age in the immature skeleton. In M. Y. Işcan, K. A. R. Kennedy (eds.), *Reconstruction of life from the skeleton*. Wiley Liss. New York: 11–21.

Jovanović B. 1969. Chronological frames of the Iron Gate group of the Early Neolithic period. *Archaeologica Iugoslavica* 10: 1–23.

Jovanović J. 2017. *The diet and health status of the Early Neolithic communities of the Central Balkans (6200–5200 BC)*. Unpublished PhD thesis. Faculty of Philosophy. University of Beograd. Beograd.

Jovanović J., Blagojević T., Živanović S., Putica A., and Stefanović S. 2017. Kontekstualna i antropološka analiza ljudskih skeletnih ostataka sa lokaliteta Topole-Bač. *Glasnik srpskog arheološkog društva* 33: 255–281.

Jovanović J., Goude G., Novak M., Bedić Ž., De Becdelièvre C., and Stefanović S. 2017. Infant feeding practices and breastfeeding strategies at the advent of the Neolithic in the Central Balkans. In J. Bazelmans (ed.), *Abstract book of the 23rd Annual Meeting of the European Association of Archaeologists 2017*. Maastricht: 152.

Jovanović J., de Becdelièvre C., Stefanović S., Živaljević I., Dimitrijević V., and Goude G. 2018. Last hunters-first farmers: new insight into subsistence strategies in the Central Balkans through isotopic analysis. *Archaeological and Anthropological Sciences* 8: 1–20. <https://doi.org/10.1007/s12520-018-0744-1>

Jovanović J., Power R. C., De Becdelièvre C., Goude G., and Stefanović S. 2021. Microbotanical evidence for the spread of cereal use during the Mesolithic-Neolithic transition in the Southeastern Europe (Danube Gorges): Data from dental calculus analysis. *Journal of Archaeological Science* 125: 105288. <https://doi.org/10.1016/j.jas.2020.105288>

Kinaston R. L., Buckley H. R., Halcrow S. E., Spriggs M. J. T., Bedford S., Neal K., and Gray A. 2009. Investigating foetal and perinatal mortality in prehistoric skeletal samples: a case study from a 3000-year-old pacific island cemetery site. *Journal of Archaeological Science* 36(12): 2780–2787. <https://doi.org/10.1016/j.jas.2009.09.004>

Korošec J. 1950. Grobovi u Vinči. *Arheološki vestnik* 1 (1–2): 156–169.

Letica Z. 1968. Starčevo and Körös culture at Vinča. *Archaeologia Iugoslavica* 9: 11–18.

Lightfoot E., Boneva B., Miracle P. T., Šlaus M., and O'Connell T. C. 2011. Exploring the Mesolithic and Neolithic transition in Croatia through isotopic investigations. *Antiquity* 327(85): 73–86. <https://doi.org/10.1017/S0003598X00067442>

Marić M., Pendić J. 2017. Analog vs. Digital documentation – cutting the costs, expanding the possibilities. Idjoš Gradište case study. *Interdisciplinaria Archaeologica VII* (2): 125–136. <http://dx.doi.org/10.24916/iansa.2017.2.2>

Marques C., Matos V., Meinzer N. 2018. Proliferative Periosteal Reactions: Assessment of Trends in Europe Over the Past Two Millennia. In Steckel R., Larsen C., Roberts C., Baten J. (eds.), *The Backbone of Europe: Health, Diet, Work and Violence over Two Millennia*. Cambridge Studies in Biological and Evolutionary Anthropology. Cambridge University Press. Cambridge: 137–174. doi: 10.1017/9781108379830.007

Masson M. 2014. *The Osteological Evidence of Neolithic Populations from the Southern Great Plain of Hungary*. Unpublished PhD thesis. Faculty of Science and Informatics. University of Szeged. Szeged.

Mathieson I., Alpaslan-Roodenberg S., Posth C., + 113 authors, and Reich D. 2018. The genomic history of south-eastern Europe. *Nature* 555: 197–203. <https://doi.org/10.1038/nature25778>

Mays S. 1998. *The Archaeology of Human Bones*. Routledge. London and New York.

2008. Septal Aperture of the Humerus in a Mediaeval Human Skeletal Population. *American Journal of Physical Anthropology* 136: 432–440. <https://doi.org/10.1002/ajpa.20826>

McClure S. B., Zavodny E., Novak M., Balen J., Potrebica H., Janković I., and Kennett D. 2020. Paleodiet and health in a mass burial population: The stable carbon and nitrogen isotopes from Potočani, a 6,200-year-old massacre site

- in Croatia. *International Journal of Osteoarchaeology* 30: 507–518. <https://doi.org/10.1002/oa.2878>
- McPherron A., Bucha V., and Aitken M. J. 1988. Absolute dating of Divostin, Grivac-Barice and Banja. In McPherron A., Srejović D. (eds.), *Divostin and the Neolithic of Central Serbia*. University of Pittsburgh. Pittsburgh: 379–387.
- Mikić Ž. 1988. Anthropological Remains from the Neolithic Sites in Serbia. In Srejović D. (ed.), *Neolithic of Serbia: Archaeological Research 1948–1988*. The University of Beograd. Faculty of Philosophy. Centre for Archaeological Research. Beograd: 20–23.
- Nehlich O., Borić D., Stefanović S., and Richards M. P. 2010. Sulphur isotope evidence for freshwater fish consumption: a case study from the Danube Gorges, SE Europe. *Journal of Archaeological Science* 37(5): 1131–1139. <https://doi.org/10.1016/j.jas.2009.12.013>
- Nemeskéri J., Lengyel L. 1976. Neolithic Skeletal Finds. In Gimbutas M. (ed.), *Neolithic Macedonia: As Reflected by Excavation at Anza, Southeast Yugoslavia*. The Regents of the University of California. Los Angeles: 375–410.
- Nemeskéri J., Szathmáry L. 1978. Individual data of the Vlasac anthropological service. In Garašanin M. (ed.), *Vlasac: mezolitsko naselje u Derdapu. Vol. 2. Geologija, biologija, antropologija*. Posebna izdanja, knj. 512. Srpska akademija nauka i umetnosti. Beograd: 285–426.
- Neuberger F. M., Jopp E., Graw M., Püschel K., and Grupe G. 2013. Signs of malnutrition and starvation: Reconstruction of nutritional life histories by serial isotopic analyses of hair. *Forensic Science International* 226(1–3): 22–32. <https://doi.org/10.1016/j.forsciint.2012.10.037>
- Obelić B., Krznarić Škrivanko M., Marijan B., and Krajcar Bronić I. 2004. Radiocarbon dating of Sopot culture sites (Late Neolithic) in Eastern Croatia. *Radiocarbon* 46 (1): 245–58. <https://doi.org/10.1017/S0033822200039564>
- Ortner D. J. 2003. *Identification of Pathological Conditions in Human Skeletal Remains*. Academic Press. New York.
- Papathanasiou A. 2011. Health, Diet and Social Implications in Neolithic Greece from the study of Human Osteological Material. In R. Pinhasi, J. T. Stock (eds.), *Human Bioarchaeology of the Transition to Agriculture*. Wiley-Blackwell. Chichester: 87–106.
- Penezić K., Porčić M., Urban P., Wittwer-Backofen U., and Stefanović S. 2020. Stressful times for women – Increased physiological stress in Neolithic females detected in tooth cementum. *Journal of Archaeological Science* 122: 105217. <https://doi.org/10.1016/j.jas.2020.105217>
- Perić S., Nikolić D. 2006. On the issue of an ossuary – pit dwelling Z in the oldest horizon at Vinča. *Starinar LVI*: 47–72.
- Porčić M., Blagojević T., Pendić J., and Stefanović S. 2021. The Neolithic Demographic Transition in the Central Balkans: population dynamics reconstruction based on new radiocarbon evidence. *Philosophical Transactions of the Royal Society B: Biological Sciences* 376: 20190712. <https://doi.org/10.1098/rstb.2019.0712>
- Powell M. L. 1985. The Analysis of Dental Wear and Caries for Dietary Reconstruction. In Gilbert R. I. Jr., Mielke J. H. (eds.), *The Analysis of Prehistoric Diets*. Academic Press. Orlando: 307–338.
- Radovanović I. 1996. *The Iron Gates Mesolithic*. International Monographs in Prehistory, Archaeological Series 11. Ann Arbor.
2000. Houses and burials at Lepenski Vir. *European Journal of Archaeology* 3(3): 330–349. <https://doi.org/10.1179/146195700807860918>
- Reitsema L. J. 2013. Beyond diet reconstruction: stable isotope applications to human physiology, health, and nutrition. *American Journal of Human Biology* 25(4): 445–456. <https://doi.org/10.1002/ajhb.22398>
- Robertson K. L., Rowland E. N., and Krigbaum I. 2014. Effects of caloric restriction on nitrogen and carbon stable isotope ratios in adult rat bone. *Rapid Communications in Mass Spectrometry* 28(19): 2065–2074. <https://doi.org/10.1002/rcm.6994>
- Roksandić M. 2000. Between foragers and farmers in the Iron Gates gorge: Physical anthropology perspective. Djerdap population in transition from Mesolithic to Neolithic. *Documenta Praehistorica* 27: 1–100. <https://www.dlib.si/stream/URN:NBN:SI:DOC-N988W3AG/3a3f7725-99c9-40bf-9f1f-8a959dba9ffe/PDF>
- Sandberg D. P., Begley J. A., and Hall C. A. 1981. The content, binding, and forms of vitamin B12 in milk. *American Journal of Clinical Nutrition* 34: 1717–1724. <https://doi.org/10.1093/ajcn/34.9.1717>
- Scheuer L., Black S. 2004. *The Juvenile Skeleton*. Elsevier Academic Press. London.
- Schwidetzky I. 1971–1972. Menschliche Skelettreste von Vinca. *Glasnik antropološkog društva Jugoslavije* 8–9: 101–112.
- Srejović D. 1969. *Lepenski Vir – Nova praistorijska kultura u Podunavlju*. Srpska književna zadruga. Beograd.

- Srejović D., Letica Z. 1978. *Vlasac: Mezolitsko naselje u Djerdapu, vol. 1 Arheologija*. Srpska akademija nauka i umetnosti. Posebna izdanja, knjiga 512. Beograd.
- Stefanović S. 2006. *Skeletni markeri okupacionog stresa u kasnoj praistoriji (2000–1500 pre n. e.): nekropola u Mokrinu*. Unpublished PhD thesis. Department of Archaeology. University of Beograd. Beograd.
- Stefanović S. 2006. The Domestication of human birth. *Documenta Praehistorica* 33: 574–581. <https://doi.org/10.4312/dp.33.15>
- Stefanović S. 2012. *Sifilis kontroverza treponematozne infekcije u evropskoj praistoriji*. Filozofski fakultet. Beograd.
- Stefanović S. 2016. *Ljudi Lepenskog Vira: bioantropološka analiza ljudskih ostataka*. Filozofski fakultet. Beograd.
- Stefanović S., Borić D. 2008. The newborn infant burials from Lepenski Vir: In pursuit of contextual meanings. In C. Bonsall, I. Radovanović, and V. Boroneanț (eds.), *The Iron Gates in prehistory: New perspectives*. BAR International Series 1893. Archaeopress. Oxford: 131–169.
- Stefanović S. Porčić M. 2015. Starčevački grobovi na Jaričstu – antropološka analiza. *Arhaika* 3: 68–88.
- Stefanović S., Jovanović J., Miljević M., and Živanović S. 2016. Starčevačka grupna grobnica na Vinči ili mesto neolitskog zločina? XXXVIII skup srpskog arheološkog društva. Vršac. 2.–4.06.2016. *Program, izveštaji i apstrakti*. Vršac: 88. <https://zenodo.org/record/1248041#.YV7RVnpvGJA>
- Stefanović S., Porčić M., Blagojević T., and Jovanović J. 2020. Neolithic Settlements in the Central Balkans between 6200 and 5300 cal BC: Issues of Duration and Continuity of Occupation. In N. Tasić, D. Urem-Kotsou, and M. Burić (eds.), *Making Spaces into Places. The North Aegean, the Balkans and Western Anatolia in the Neolithic*. BAR International Series S3001. British Archaeological Reports (Oxford) Ltd. Oxford: 191–169.
- Stojanova Kanzurova E. E. 2020. Novi saznanja od tretnog kulturnog horizonta na neolitska naselja Tumba Mađžari, Skopje (arheološki istraživanja u periodu 2002–2005 i 2012 godina). *Macedoniae acta archaeologica* 22: 9–28.
- Stojanovski D., Živaljević I., Dimitrijević V., + 15 authors, and Stefanović S. 2020. Living off the land: Terrestrial-based diet and dairying in the farming communities of the Neolithic Balkans. *PLoS ONE* 15(8): e0237608. <https://doi.org/10.1371/journal.pone.0237608>
- Tasić N., Srejović D., and Stojanović B. 1990. *Vinča: Centre of the Neolithic culture of the Danubian region*. Cultura. Beograd.
- Tasić N. N., Marić M., Bronk Ramsey C., +5 authors, and Whittle A. 2015. Vinča -Belo Brdo, Serbia: The times of a tell. *Germania* 93: 1– 75.
- Tasić N. N., Marić M., Filipović D., +6 authors, and Whittle A. 2016. Interwoven Strands for refining the Chronology of the Neolithic tell of Vinča-Belo Brdo, Serbia. *Radiocarbon* 58(4): 795–831. <https://doi.org/10.1017/RDC.2016.56>
- Torgersen J. 1951. The developmental genetics and evolutionary meaning of the metopic suture. *American Journal of Physical Anthropology* 9: 193–210. <https://doi.org/10.1002/ajpa.1330090206>
- Tripković B. 2011. Containers and grains: food storage and symbolism in the Central Balkans (Vinča period). *Documenta Praehistorica* 38: 159–172. <https://doi.org/10.4312/dp.38.13>
- Ugga L., Cuocolo R., Cocozza S., +5 authors, and Imbriaco M. 2018. Spectrum of lytic lesions of the skull: a pictorial essay. *Insights into imaging* 9(5): 845–856. <https://doi.org/10.1007/s13244-018-0653-y>
- Vasić M. 1932. *Preistoriska Vinča. 1. Industrija cinabrita i kosmetika u Vinči: uvod i proučavanje Vinče: sa dodacima: I. Vezano božanstvo u preistorijskoj religiji. II. Vinča i hiperborejski mit*. Državne štamparije Kraljevine Jugoslavije. Beograd.
1936. *Preistoriska Vinča 2*. Državne štamparije Kraljevine Jugoslavije. Beograd.
- Veljanovska F. 1998. *Antropološke karakteristike stanovništva na tlu R. Makedonije od neolita do srednjeg veka*. Unpublished PhD thesis. Faculty of Philosophy. University of Beograd. Beograd.
2001. Neolitski skeletni naodi od Pista – Novo Selo. *Macedoniae Acta Archaeologica* 17(1999–2001): 341–350.
2017. Cerje-Govrlevo: A Neolithic Skeleton from Govrlevo near Skopje. In E. Stojanova Kanzurova (ed.), *Dragiša Zdravkovski In Memoriam. Cultural Manifestations during the Neolithic Period on the Territory of the Republic of Macedonia and neighboring Regions*. Archaeological Museum of Macedonia. Skopje: 69–78
- Waldron T. 2009. *Palaeopathology*. Cambridge University Press. Cambridge.

- Walker P. L., Barthurst R. R., Richman R., Gjedrum T., and Andrushko V. A. 2009. The Causes of Porotic Hyperostosis and Cribra Orbitalia: A Reappraisal of the Iron-Deficiency-Anemia Hypothesis. *American Journal of Physical Anthropology* 139: 109–125. <https://doi.org/10.1002/ajpa.21031>
- Wei S., Stevens T. M. 2014. Benign Tumors and Tumor-Like Conditions of Bone. In L. M. McManus, R. N. Mitchell (eds.), *Pathobiology of Human Disease*. Elsevier Academic Press. Amsterdam: 838–855.
- Whittle A., Bartosiewicz L., Borić D., Pettitt P., and Richards M. 2002. In the beginning: new radiocarbon dates for the early Neolithic in northern Serbia and south-east Hungary. *Antaeus* 25: 63–117.
2005. New Radiocarbon Dates for the Early Neolithic in Northern Serbia and South-East Hungary: Some Omission and Corrections. *Antaeus* 28: 347–355.
- Wittwer-Backofen U., Tomo N. 2008. From Health to Civilization Stress? In Search for Traces of a Health Transition During the Early Neolithic in Europe. In J. Bocquet-Appel, O. Bar-Josef (eds.), *The Neolithic Demographic Transition and its Consequences*. Springer. Dordrecht: 501–538.
- y'Edynak G. 1978. Culture, diet, and dental reduction in Mesolithic forager-fishers of Yugoslavia. *Current Anthropology* 19: 616–618.
- Zalai-Gaál I. 1994. Betrachtungen über die kultische Bedeutung des Hundes im mitteleuropäischen Neolithikum. *Acta Archaeologica Hungarica* 46: 33–57.
2009. *Zur Herkunft des Schädelkults im Neolithikum des Karpatenbeckens*. Archaeolingua. Budapest.
- Zoffman Z. 1987. Das anthropologische Material des spät-neolithischen Gräberfeldes von Hrtkovci-Gomolava. *Rad Vojvodjanskih Muzeja* 30: 43–69.
- Živaljević I. 2015. Concepts of the body and personhood in the Mesolithic-Neolithic Danube Gorges: interpreting animal remains from human burials. *Etnoantropološki Problemi* 10(3): 675–699.
2017. *Ribolov na Đerdapu u ranom holocenu (10.–6. milenijum p.n.e.)*. Unpublished PhD thesis. Faculty of Philosophy. University of Beograd. Beograd.
- Živaljević I., Stefanović S. 2016. (Dis)continuities in fishing practices at the onset of Neolithic: a case study from Starčevo, Serbia. *22nd Annual Meeting of the EAA. 31st August 4th September 2016 Vilnius. Abstracts*. www.Eaavilnius 2016. It. Vilnius: 151.
- Živaljević I., Dimitrijević V., and Stefanović S. 2017. Faunal remains from Kula, a Mesolithic-Neolithic site at the exit of the Danube Gorges (Serbia). In M. Mărgărit, A. Boroneanț (eds.), *From Hunter-Gatherers to Farmers: Human Adaptations at the End of the Pleistocene and the First Part of the Holocene: Papers in Honour of Clive Bonsall*. Editura Cetatea de Scaun. Târgoviște: 113–133.
- Živaljević I., Dimitrijević V., Jovanović J., + 10 authors, and Stefanović S. 2021. Revealing the “hidden” Pannonian and Central Balkan Mesolithic: new radiocarbon evidence from Serbia. *Quaternary International* 574: 52–67. <https://doi.org/10.1016/j.quaint.2020.11.043>