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THE TALKING DEAD [2]

PAST AND PRESENT OF BIOLOGICAL ANTHROPOLOGY THE HERITAGE OF TÖRÖK AURÉL'S OEUVRE

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Past and Present of Biological Anthropology
The Heritage of Török Aurél's Oeuvre
New results from ancient tuberculosis and leprosy research

Proceedings of the Second International Conference of the
Török Aurél Anthropological Association
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EDITOR
SZILÁRD SÁNDOR GÁL

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CONTENTS

THE LIFE AND WORK OF TÖRÖK AURÉL

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Aurél Török (Aurél Ponori Thewrewk by his birth name) was born on the 13th of February 1842 in Pozsony (Bratislava, present-day Slovakia) in the year when Anders Retzius published his famous work. His father, József Thewrewk was a lawyer, famous art collector and polyhistor. His collection was damaged twice seriously, therefore he moved to Pozsony, and started a family there. He had three children: Emil, Árpád and Aurél. Aurél Török graduated from the Piarist High School of Budapest, and completed six semesters at the Medical Faculty of the University of Budapest between 1861 and 1863. He spent the next four semesters at the Medical Faculty in Vienna, and was awarded a medical degree on the 22nd of October 1867. From the fall of 1867 to July 1869 he functioned as a junior lecturer for four semesters in the Institute of Physiology of the University of Budapest, meanwhile also teaching chemistry and technology at the Budapest Academy of Commerce. During his university studies he had already helped József Lenhossék as a teaching assistant in his second year, and translated German, French and English articles for the journal Gyógyászat (Medicine) in his third year of medical studies. On the 24th of May 1869 he has been elected as professor of embryonal and histological development in the Medical Faculty in Budapest. On the 29th of July 1869 he has been appointed by baron József Eötvös minister as professor of physiology, histology and medical physics, and also as interim professor of pathology and forensic medicine in the Institute of Medical Surgery of the College of Kolozsvár (Cluj-Napoca, present-day Romania), where he taught for four semesters.

Török, however, has been more interested in research than education. Therefore, in the summer break of 1869 he visited several universities in Germany. From September 1871 he studied and did independent research in Bonn, Tübingen, and Würzburg with special permission of the minister. He published several German papers about the results of these visits. From April to September 1872, he studied the education and research scheme of the University of Strasbourg. From the fall of 1872, he was appointed as professor of physiology and histology at the Faculty of Medicine of the college turned university of Kolozsvár. He had kept this appointment until the fall of 1878.

In 1878, the director's position at the Department of Pathology in Kolozsvár became vacant following the death of professor Cziffra. The position has been offered to Nándor Klug, but he desired Török's position. Therefore, the Professors' Committee requested Török to head the Department of Pathology. Minister Ágoston Trefort issued a permission to transfer Török to the Department of Pathology as a professor on the 8th of August 1878, with the appointment starting on the 3rd of December 1878.

At his new department, Török started systematical analysis of the skull collection assembled by the late professor Cziffra. From the fall of 1978, he also started racial studies of the corpses dissected for educational purposes. The 36 year-old Török, the professor of physiology and histology in Kolozsvár, married with children, after 12 years of professional career in his original discipline decided to do anthropological research.

To gain more insight, he participated the Paris International Exposition and the Congress of the Anthropological Society in 1878. These events had a major impact on his later career. At the Congress of the Anthropological Society held at the world expo, he found that skulls of convicts executed for murder and robbery were exhibited there as true Hungarian types provided by Benedikt. The next day he brought this up to Paul Broca, who snapped back at him saying „You noble Hungarians come here to complain, are you only capable of talking? Here you should only argue using facts. Did you bring any skulls with you to disprove dr. Benedikt... Don't you think it is worth studying your own race? Where are your skull collections? When I visited Budapest, Lenhossék also showed me skulls of Hungarian convicts." Török replied: „I am not an anthropologist, I'm a professor of physiology." Broca interrupted him: "If you're not an anthropologist yet, you need to become one. Come and join us for a year, and we're going to train you."

Török really paid heed to these words. Already during the fall of 1878, he launched an anthropology section in the journal Természettudományi Közlöny (Bulletin for Natural Sciences). In 1879, he was the first ever to launch anthropology lectures at a Hungarian university. In 1880–81 he travelled to Germany at his own expenses for a one year study trip, he visited the anthropological collections in Basel and Geneva, where Broca was also working. In March 1881, Ernest Hamy requested him to co-author the book titled „Crania Ethnica". In 1881 he participated excavations along the borders of Algeria and Tunisia, and also in Switzerland. During his study trip, he translated Paul Topinard's book titled "Anthropologie" with Gyula Pethő to Hungarian, where he defined Hungarian anthropological nomenclature for the first time.

After such history, emperor Franz Josef signed a document at the military practice manoeuvres near Mezőkövesd, allowing Ágoston Trefort minister to appoint Török as director of the new Department of Anthropology in Budapest. Sámuel Scheiber had already made an unsuccessful attempt earlier to found an anthropology department. On the 19thof August 1881, Török requested his own relief of the duties at the pathology department in Kolozsvár.

Ágoston Trefort minister called upon Török to outline his plans on the 16thof October 1881. Török proposed the following agenda at the faculty meeting of the 16thof December 1881:

1. overview of the current state of the field of anthropology,
2. plans of anthropology lectures,
3. calling and directions of the scientific work atthe new anthropology institute in Budapest,
4. proposal for the equipment of the anthropological museum to be founded,
5. proposal for the equipment of the anthropology department and institute,
6. layout of the anthropology institute.

Török described the main disciplines of anthropology as follows: biological anthropology, ethnological anthropology, demographic anthropology, prehistoric anthropology.

He requested to hire one professor, one junior lecturer, one preparator, one servant, and also asked for 10500 forints for expenses. The department was assigned rooms in the main building of the university that had formerly functioned as an apartment with a 64,85 m^2 total area (2 small rooms, 1 big room, one kitchen and one pantry). On the 25thof April 1883, Török informed the dean of the faculty, that the assigned workspace is not sufficient for the purposes of the department, they don't even have a chamber to perform dissections. In another request on the 22ndof October 1884 to baron Lóránd Eötvös, minister for religion and public education, Török states that they don't have a lecture room, library, laboratory, their collection is housed in the attic and the basement. Earlier on 27thof May 1884, he had already requested the enlargement of the department area to 444 m^2. As a result, the minister allowed to move the department to the new building of the university on the Múzeumkörút (boulevard). The department area here grew to 446,89 m^2, and 26880 forints were provided for equipment.

The collection of the anthropology museum was based on the human skull collection offered by the Hungarian National Museum that mainly came from archaeological excavations. As of May 1884, the collection consisted of 1500 skulls, 25 full skeletons, 70 plaster copies, 40 preserved brains. Between 1886 and 1894 the museum's collection grew with 10000 skulls and 1000 skeletons. Eventually Török had no space to house this material, therefore he requested to move the collection to the Department of Ethnology in the Városliget (City Park), which has been approved by the Hungarian National Museum in 1906. This administrative move was the first step in the creation of the current Department of Anthropology at the Hungarian Natural History Museum finally implemented in 1945.

He made significant contributions to the study and housing of the Árpádian kings' remains, thus, to the appreciation of Hungarian national traditions.

Török had serious plans concerning education. He took meticulous notes of his students. From these we know he only had 2 students in the academic year of 1881–1882, while 174 students attended his lectures in the winter semester of 1903–1904. Between 1881 and 1912 he administered 2732 students total. In the new department, he started his first lecture on the 3rd of October 1881. His first students were Gusztáv Thirring and Károly Pápai (Schip). Some of his students later worked with him, including Gyula Grittner, János Jankó, László Dobsa, Károly Teszák, Jenő Hillebrand. Others like Kálmán Lambrecht, Mariann Kubáss, Béla Balogh, László Nánásy, Katalin Gstettner have also worked in the field of anthropology for a shorter or longer period of time. During his professorial supervision, 23 doctoral theses were written, starting with the thesis of István Molnár, a teacher form Hajdúböszörmény.

Török had a lot of scientific debate with his peers. Two of his major debates were with László Réthy and Julius Kollmann. With the latter, tension was formed around methodological issues, which drove Török to start a thorough reform of craniometry. He constructed several ingenious measuring tools, and put craniological analysis on a mathematical basis. This is why Kollmann mockingly called him "the reformer of craniometry from Pest". Török was a major critique of the works of Károly Pápai, one of his most talented student. He also had serious debates with Ottó Herman and János Jankó, which eventually lead to anthropology losing its two promising talents at the turning of the century. Török gave interesting, diverse, but unsystematic lectures, his students were left alone with practical issues. His personality was extreme, oversensitive, and quick-tempered.

The fight for anthropology, for supplies, the debates with his sponsors took their toll on Török's mental health. Already on the 17thof October 1898 he had to ask for a two weeks long sick leave. He complained that he had never been sent on any official study trips during his 20 years of efforts. In the academic year of 1907–1908 he served as the rector of the university, which further deteriorated his health. His long-standing atherosclerosis, asthma, and aortic aneurysm caused symptoms again. He went on a one month holiday in 1908, and took medical treatments in Vienna and by the Adriatic. He spent parts of the academic year of 1908–1909 in bed. Even though he restarted his lectures in the fall of 1909, his recovery was only temporary. On the 2ndof September 1912, the night before the opening of the Anthropological Congress in Geneva he was struck dead. He was still full of plans and lust for work. His grave under state protection can be found in the Farkasréti cemetery in Budapest.

For almost four decades, he has been the sole representative of Hungarian anthropology that he is the funding father of. His work reflected in 164 Hungarian and foreign language papers in almost all subfields of anthropology is everlasting. After his death, the department was headed by József Lenhossék. Between 1919 and 1930 the department chairman was zoologist Lajos Méhely, who had extreme racial beliefs. Permanent anthropology professor has only been appointed to lead the department in February 1959, when Török's former student Lajos Bartucz was assigned the role. Bartucz executed Török's plan long after his death, and trained many new scientists who later achieved significant results. The life and work of Aurél Török has been exemplary in the past, and it may remain so for the present and the future, inspiring the revival of Hungarian anthropology.

Acknowledgement

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Papers of the life and work of Aurél Török

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Figure legends

Figure 1: A portrait of AurélTörök (original photography by A. Weinwurm, digitalized by Luca Kis).

Figure 2: Measuring tools designed by AurélTörök (photography by Luca Kis).

Figure 3: Wreath laying ceremony on the 100th anniversary of Török's death in 2012.

Figure 4: Török's tombstone in the Farkasréti cemetery at the time of the 100th anniversary of his death in 2012.

Figure 1

Figure 2

Figure 3

Figure 4

THE IDENTIFICATION OF HORSE RIDING THROUGH THE ANALYSIS OF ENTHESEAL CHANGES: METHODOLOGICAL CONSIDERATIONS

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Keywords: Entheseal changes; Activity-related skeletal markers; Horse riding; Hungarian Conquest period

Abstract

In certain conditions, some changes observed on the bones can be related to an intense and regular physical activity during the life of individuals. The changesobserved at the attachment sites of the muscles, the entheseal changes (EC), are among the most commonly used markers for the reconstruction of activities in past populations. Horse riding, in particular, has already been investigated in bioarchaeology, but various methodological limitations result in a lack of confidence and reliability regarding the skeletal changes that should be considered as specific for this activity. We present here methodological aspects and the numerous limitations related to the use of EC for the reconstruction of activities and introduce the broad bioarchaeological analysis of horse riding that we performed on remains of ancient Hungarians from the Conquest period (10th century CE), known for using armies of mounted archers. This investigation includes the scoring of EC for entheses related to muscles involved in horse riding, as various EC have already been interpreted by authorsas markers for this activity. The final aim of this research is to improve the identification of horse riders in osteoarchaeological collections.

Introduction

The beginning of the use of horses for transportation, possibly around 3500 years BCE in the Kazakh steppe with the domestication of the horse, significantly influenced the history of human cultural evolution, with an impact on majors aspects such as trade, settlement, warfare or social organization[1] . In certain conditions, different types of skeletal changes can provide

[1] Anthony, 2007; Anthony and Brown, 1991; Outram et al., 2009.

information on the activities performed during life, such as horse riding[2]. If we can put in relation some skeletal changes observed on horse remains with the equestrian activity[3], this link is not reliably demonstrated yet regarding human remains.

There are many challenges in the attempt to provide information on the activities of past populations[4]. In addition to the limitations related with the analysis of the activity-related skeletal markers, one of the main issues encountered in the specific literature is that activities are often inferred without a link to potential evidence from archaeological, ethnographic or historical sources. As a result, bone changes, considered to be related to specific activities in past populations, may be over-interpreted, or, on the contrary, undervalued. This impedes the ability to achieve a more comprehensive view of human cultural evolution processes. Therefore, the selection of well-documented materials is determinant for the study of activities.

The bioarchaeology of horse riding is a dynamic research topic, especially since the beginning of the 1990s and the studies of Miller and Pálfi on remains of historic Native Americans and early Hungarian conquerors, respectively[5]. Regarding the latter in particular, we know from historical sources that the Hungarians tribes who conquered the Carpathian Basin from the end of the 9th century and during the 10th century CE were composed of powerful armies of archers mounted on horses. They let many rich cemeteries from the Conquest period, where we can often find archery (arrowheads, bow plates, quivers) and horse riding (stirrups, bits, elements of the saddle) equipment, or also horse bones, intentionally deposited in the graves[6]. The presence of these items associated with the individuals suggests that they were practicing those activities and it represents an opportunity to put in relation the changes observed on the skeletal remains and the archaeological grave goods.

Among all types of skeletal changes, entheseal changes (EC), at the muscle attachment sites, have been extensively used for decades as activity or occupational stress markers[7]. This paper presents how EC have been associated with the practice of horse riding in archaeological samples, and it also discusses the limitations related to this type of research. EC are part of a broad macromorphoscopic analysis that we performed on a series of Hungarians from the Conquest period. The final aim is the identification of bone markers reliably related to the practice of horse riding during life. This will allow identifying the presence of horse riders in anthropological collections, thus providing information on the lifestyles and organization of past populations.

Entheseal changes as activity-related markers and their limitations

Entheseal changes (EC) are pathological or non-pathological modifications at the insertion sites of tendons, ligaments and joint capsules on the bone[8]. A distinction can be made between fibrous entheses, mainly encountered at the metaphyseal or diaphyseal areas, and fibrocartilaginous entheses, that include the insertions at the epiphyses and processes of long bones as well as the short bones of hands and feet and several ligaments in the spine[9]. EC result in bone alterations visually observable on dry bone. It can take the form of mineralized tissue formation (eg. irregular

[2] Jurmain et al., 2012.
[3] Bulatović et al., 2014; Pluskowski et al., 2010; Taylor et al., 2014.
[4] Dutour, 1992; Jurmain et al., 2012.
[5] Miller, 1992; Miller and Reinhard, 1991; Pálfi, 1992; Pálfi and Dutour, 1996.
[6] Révész, 2003.
[7] Al-Oumaoui et al., 2004; Baker et al., 2012; Dutour, 1986; Hawkey and Merbs, 1995; Henderson and Alves Cardoso, 2013; Pálfi and Dutour, 1996; Villotte et al., 2010.
[8] Benjamin et al., 2002; La Cava, 1959; Lagier, 1991; Niepel and Sit'aj, 1979.
[9] Benjamin and McGonagle, 2001; Benjamin and Ralphs, 1998.

surface) and bone formation (raised margin, enthesophyte, etc.) as well as surface discontinuity such as fine and macro-porosity, cortical defect, erosive areas, cavitations, etc[10].

EC can be related to age and sex but can also result from various causes like metabolic or inflammatory disorders, acute traumas, as well as mechanical stress[11]. As one of the fundamental roles of an enthesis is stress dissipation, distributing load forces across the bone[12], EC have been considered for decades as occupational stress markers to reconstruct the activities of past populations.

The multifactorial nature of the EC leads to the need to consider various aspects. First, the analysis of EC should take into account age differences in the sample as it is acknowledged that older individuals display more EC and more robust entheses than younger ones[13]. This could result from the fact that older individuals experienced more stress related to activities during their life, but also from changes of bone structure, as bone remodeling becomes slower with age[14].

Similarly, the sex of the subjects is determinant for the analysis of EC as the frequent differences observed between females and males are often interpreted in terms of differences in activities, thus leading to interpretations on the organization of societies[15]. Particularly, it remains unclear if the females and males develop robusticity at the entheses in a similar way or if there is an important role played by hormonal processes[16].

Beside those confounding variables that must be recognized, the use of EC for reconstructing activities is greatly limited by a lack of specificity of the changes[17], which is closely related to the multifactorial aetiology of the EC. To summarize, the practice of an activity might not systematically result in the development of the same skeletal changes in different individuals, and identical bone changes in different subjects may be related with different activities and various other causes.

Another major issue is the lack of correspondence between the activities of the past populations and contemporary reference samples[18]. Even in some cases, like for horse riding, when comparisons can be made between archaeological and modern data, one should keep in mind that the techniques and the equipment that are used today generally differ from those used in the past, thus resulting in possible differences in gestures and muscle solicitation, although these differences might be only tenuous.

Finally, the method of scoring of the EC is another crucial aspect to consider, as it can limit the possibilities of comparisons between different studies and it directly has an impact on the interpretations of the results. Entheses and their changes have been extensively studied, with clinical, radiological, histological and osteological methods at the macroscopic and microscopic scales[19]. More recently, the 3D approach, as well as to modensitometry and micro to modensitometry, have also begun to be used as a tool for studying EC[20]. Regarding visual macromorphoscopic examination, which involves smaller costs and time efforts, several systematic ranking and descriptive methods have been elabo-

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[10] Hawkey and Merbs, 1995; Mariotti et al., 2004; Robb, 1998; Villotte, 2006; Villotte et al., 2016.

[11] Claudepierre and Voisin, 2005; Dutour, 1992; Henderson and Alves Cardoso, 2013; Milella et al., 2012; Niinimäki and Baiges Sotos, 2013; Paja et al., 2010; Slobodin et al., 2007; Villotte and Kacki, 2009; Villotte and Knüsel, 2013.

[12] Benjamin and McGonagle, 2001.

[13] Robb, 1998; Weiss, 2004.

[14] Weiss, 2004.

[15] Hawkey and Merbs, 1995; Lieverse et al., 2009; Molnar, 2006.

[16] Tichnell, 2012.

[17] Dutour, 1992; Jurmain et al., 2012.

[18] Dutour, 1992; Jurmain et al., 2012.

[19] Benjamin et al., 2002; Claudepierre and Voisin, 2005; Cooper and Misol, 1970; Henderson, 2013a; Henderson et al., 2016a; Junno et al., 2011; Maffulli et al., 2005; Miszkiewicz and Mahoney, 2016; Olivieri et al., 1998; Resnick and Niwayama, 1983; Schlecht, 2012; Villotte, 2009.

[20] Djukic et al., 2015; Henderson, 2013b; Karakostis and Lorenzo, 2016; Noldner and Edgar, 2013; Nolte and Wilczak, 2013; Pany et al., 2009.

rated, following the work of Hawkey in 1988[21]. Some attempts of standardisation have also been proposed, following a more descriptive procedure[22], however, they focus only (but judiciously) on the fibrocartilaginous type of enthesis and involve the division of the entheses into two zones, at the margin and on the surface. This distinction requires precise knowledge regarding the anatomy of the entheses and the authors provide, so far, information for only a few of them. Furthermore, more work is needed to test the influence of age and activities. Alternatively, due to anatomical considerations (especially the acknowledgement of the distinction between the fibrocartilaginous and fibrous entheses), as well as the fact that the link between the observed changes, the different stages of ranking and the activities is still questioned, some prefer to use binary recording methods[23]. This also improves the ability to make comparisons between various materials and studies, and this is the solution that we adopted in the frame of our broad analysis of ancient Hungarian materials.

The entheseal changes and the practice of horse riding

Regarding the bioarchaeology of horse riding, EC are one of the most common types of skeletal changes mentioned in the literature. The authors put in relation some EC observed on the bones with the regular and intense practice of riding.

The entheses that are the most frequently cited cover various origin and insertion sites on the pelvis and the lower limbs (Plate no. 1, Fig. 1, Plate no. 2, Fig. 2):

– the coxal bone, at the ischial tuberosity (biceps femoris, semitendinosus, quadratus femoris, semimembranosus) and the posterior face of the ilium (gluteus maximus, gluteus medius, gluteus minimus)[24];

– the femur, at the greater trochanter (gluteus medius, gluteus minimus), the trochanteric fossa (obturator externus, obturator internus), the lesser trochanter (iliopsoas), the gluteal tuberosity (gluteus maximus), the spiral line (vastusmedialis), the pectineal line (pectineus), the lineaaspera (adductor longus, adductor magnus, adductor brevis, vastusmedialis, vastuslateralis, biceps femoris), the adductor tubercle (adductor magnus) and the insertions of the gastrocnemius at the posterior surface of the distal extremity[25];

– the patella, on the anterior surface (quadriceps femoris)[26](Józsa et al., 1991; Pap, 1985);

– the tibia, at the tibial tuberosity (quadriceps femoris) and the soleal line (soleus)(Belcastro et al., 2001; Fornaciari et al., 2007);

– the calcaneus, at the calcaneal tuberosity (triceps surae) (Belcastro et al., 2001; Khudaverdyan et al., 2016).

Those entheses are related to muscles that cover a wide range of movements involved in the position of the rider, who needs particularly strong postural muscles, and especially the adductors (hip adduction), the gluteals (hip extension, abduction, medial and lateral rotation), the quadriceps (knee extension, hip flexion), the hamstring (knee flexion, hip extension), the hip rotators (hiplateral rotation) and the calf muscle (plantarflexion). Among them, the adductors are often presented as particularly important for riding as they keep the legs together on the horse, which is not a common action otherwise (Djukic et al., 2018; Willson, 2013).

[21] Hawkey and Merbs, 1995; Henderson et al., 2013; Mariotti et al., 2004, 2007; Villotte, 2006).
[22] Henderson et al., 2016b; Henderson et al., 2016c.
[23] Alves Cardoso and Henderson, 2010; Villotte et al., 2010.
[24] Djukic et al., 2018; Miller, 1992; Pálfi, 1992.
[25] (Alduc-Le Bagousse et al., 1992; Anđelinović et al., 2015; Belcastro et al., 2001; Blondiaux, 1994; Courtaud and Rajev, 1998; Djukic et al., 2018; Fornaciari et al., 2014; Fornaciari et al., 2007; Józsa et al., 1991; Khudaverdyan et al., 2016; Molleson and Blondiaux, 1994; Pálfi, 1992; Pap, 1985; Reinhard et al., 1994; Tichnell, 2012.
[26] Józsa et al., 1991; Pap, 1985.

If many studies use the presence of EC on the pelvis and the lower limbs to infer the practice of horse riding during the life, we can deplore that the numerous limitations mentioned previously are not systematically considered. Furthermore, methodological differences in the scoring limit the possibilities for comparisons.

Apart from the consideration of those limitations, one major aspect that can improve the interpretations and the identification of riders in archaeological materials is the relevance of the study materials itself. While it must not be considered as absolute evidence, only the presence of archaeological goods related to equestrian activity in the grave may represent a robust indicator that one particular individual might have been a rider. Unfortunately, this direct link between the individual and the activity is missing in most of the studies as they often rely only on the fact that the subjects belong to a group or population presumed to have used horses.

In addition, the studies relying on direct archaeological evidence rarely concern more than just a handful of subjects (when not only one), which impedes the ability to perform systematic observations and to identify reliable specific changes. The studies led by Belcastro and collaborators (Belcastro et al., 2007; Belcastro and Facchini, 2001; Belcastro et al., 2001) stand out, with a sample size of 13 presumed horsemen allowing a repetition of the observations and measurements, and by explicitly providing information about this group in the population, identified from archaeological evidence in the graves.

The analysis of Early Hungarian mounted archers

The methodological limitations and the frequent absence of a direct link between the subjects and the activity of riding result in a lack of confidence and reliability regarding the skeletal changes that have been identified as horse riding-related.

Our research uses one of the most pertinent osteoarchaeological materials for the analysis of horse riding-related skeletal changes, a collection of early Hungarians from the Conquest period. Keeping in mind the numerous limitations mentioned for the reconstruction of activities (e.g. Dutour, 1992; Jurmain et al., 2012), we included in this study only adult males, in order to limit the influence of non-mechanical factors such as hormonal and developmental changes. The scoring of the EC covers the majority of the attachment sites cited in the literature and that are related to muscles involved in riding. Suspicious cases of inflammatory or metabolic disorders, such as spondylarthropathies and DISH that might affect the entheses, were excluded.

The broad examination that we performed on this series includes alsodifferent types of skeletal changes that allowscovering from a wide angle the response of the bone to physical pressure. Through the systematic analysis of EC, joint changes, vertebral changes, morphological variations, traumatic lesions and shape and robusticity indices, we expect to distinguish independent markers that can reliably be related to the practice of horse riding. Multivariate statistical analyses might also allow us to identify a set of combined markers that would significantly improve the identification of riders. The presence or absence of each type of changes was systematically recorded, and a large series of measurements were taken on the bones of the lower limbs and the pelvis. Both sides were consideredin order to assess the question of the asymmetry.

These data were compared between two subsambles of adult males from the Hungarian cemetery of Sárrétudvari-Hízóföld, a group of individuals with riding equipment and horse bones in the graves and a group of subjects without such deposit related to horses. Significant differences between these two groups will allow us to discuss the link between some of those changes and the practice of horse riding. Furthermore, a third group was used for out-sample comparison, to improve our chances to identify markers specific to horse riding. This group of presumed non-riders comes from the documented Luís Lopes Skeletal Collection (National Museum of Natural History and Science, MUNHAC), Lisbon (Alves Cardoso and Henderson, 2013; Cardoso, 2006). They were individuals of known occupation who were living in Lisbon mainly during the first half of the 20th century. The first results of those comparisons between three groups already revealed to be promising regarding the adaptation of the shape of the acetabulum to the practice of horse riding (Berthon et al., 2018).

In addition to the macromorphoscopic observations, we also attempted to investigate the microarchitecture of the entheses through microtomodensitometric acquisitions and 3D reconstructions(Berthon et al., 2015; Berthon et al., 2016). The aim was to determine if it is possible to distinguish some differences in the microstructure of the enthesis according to its probable cause, as we discussed that the multifactorial aetiology of the EC remains a major issue for their interpretation in terms of activities. We performed a preliminary investigation on the bicipital tuberosity of the radius, on a subject with EC probably related to a metabolic disease, another one (an ancient Hungarian conqueror with archery equipment in his grave) who displayed changes probably resulting from the practice of archery, and a last one without visible changes at the surface. This exploratory research revealed a difference in the organization of the canals in the cortical bone of the entheses. Further work may lead to the possibility to distinguish the cause of the EC and improve the interpretations in terms of activities.

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Figures

Figure 1. (Plate no. 1) Entheseal changes mentioned in literature as being related to the practice of horse riding, on the: a) coxal bone, at the ischial tuberosity; b) patella, anterior surface; c) calcaneus, at the calcaneal tuberosity; and d) the tibia, at the soleal line.

Figure 2. (Plate no. 2) Entheseal changes mentioned in literature as being related to the practice of horse riding, on the femur, at the: a) greater trochanter; b) trochanteric fossa; c) lesser trochanter; d) gluteal line; e) lineaaspera (medial and lateral); and f) the adductor tubercle.

Figure 1

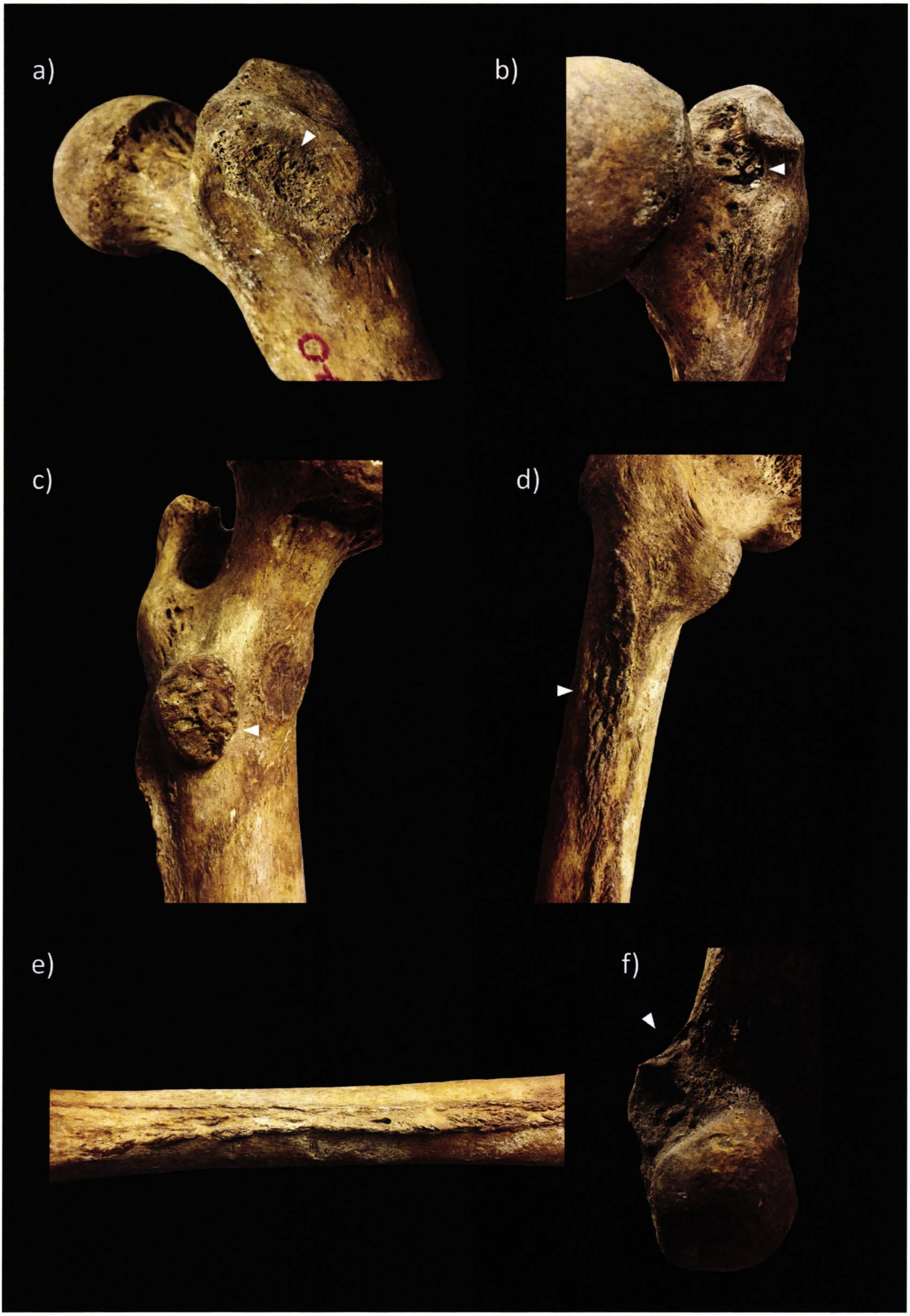

Figure 2

HISTORICAL EVIDENCE OF TUBERCULOSIS IN BUCHAREST (ROMANIA)

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Keywords: 20th century tuberculosis, Rainer Osteological Collection, statistical yearbooks, (Bucharest) Romania.

Abstract

During medieval and modern periods, tuberculosis (TB) was one of the major factors of natural selection that influenced the evolution of Bucharest population and the other regions inhabited by Romanians. In order to better grasp the incidence of this disease and its effect on the population of Bucharest, for the study were used several sources of information that present the disease differently and cover four centuries of Bucharest history. The aim of the study is to obtain representative data on the incidence of the disease in the studied area and period. Several common elements typical for the spreading pattern of infectious diseases were identified in all used sources. The vast majority of individuals suffering from TB fall in the 14–49 age interval, women die at younger ages than men, the mainly urban population is more affected, and M. Tuberculosis seems to the main agent in spreading the disease.

Introduction

In almost all instances, bone tuberculosis (TB) is a secondary infection hematogenously transmitted from the lungs or lymph nodes. The result on the bones is the same regardless of the way of infection[1], and it is caused by a bacteria species generically named *Mycobacterium tuberculosis*. The most common form of infection is air-borne, manifested most frequently through lung and lymph infection. Another form of transmission is through the gastrointestinal system and, subsequently, through the lymph system, following the consumption of infected animal products. In this case, the causative agent is *Mycobacterium bovis*. The first form of the bacteria is favoured by crowded urban centres, while the latter is more frequent in farming communities[2].

The pathogenesis of the disease depends on the individual's immune system, on the virulence and inoculated quantity of the causative agent, thus in certain cases the bacteria disseminate hematogenously from the initial point of infection to other parts of the human body, including the skeleton, resulting in extra-pulmonary tuberculosis[3]. On the skeleton, it tends to locate on the parts rich in hematopoietic marrow, usually present in the cancellous bone. The disease usually manifests as multiple tuberculous skeletal foci, the most common and characteristic lesions being the lytic destruction on the anterior side of the vertebral bodies, of the hip, knee, ankle and elbow joints,

[1] Panuel et al. 1999.

[2] Manchester, 1991.

[3] Aufderheide& Rodriguez-Martin 1998: 118; Ortner 2003, 141, 227; Roberts &Buikstra 2003: 5; Waldron 2009, 90–92; Spekker& al. 2012: 116.

and mainly in non-adults, lytic lesions on tubular bones and skull[4]. Although periosteal reaction on the ribs is meagre in TB, but not unusual[5], when associated with the disease it affects mainly the middle ribs and more extensively the left side[6].

In 2013, in Romania, 1,136 deaths among 19,983,471 people occurred due to TB (ASR 2015: 50, 76–77), compared to 32,277 deaths in 1939 for a population of 19,933,802 (ASR 1940: 42, 174). For the period of 1875–1936, in Bucharest (the capital), TB deaths accounted for 15.66% average of all deaths. Practically TB was one of the major factors of natural selection that influenced the evolution of Bucharest population and of Romanian provinces in general, at least in the medieval and modern periods. In order to better grasp the incidence of this disease and its effect on the population of Bucharest, we used several sources of information that present the disease differently, aiming at obtaining representative information for the reality of the respective periods.

Identification data and cause of death of the specimens in Rainer Osteological Collection were used as the reference for TB mortality in the first half of the 20th century. To complete and verify the osteological data, the historical texts for 18th–19th centuries and the statistics annuals of Bucharest for 1880–1936 were also studied.

Materials and methods

Three types of sources were analysed in this study: historical data, statistics yearbooks and the Rainer Collection recorded data. Broadly, they can be divided into first-hand sources (records of descriptions from witnesses or people that lived around the event) and indirect sources (texts written subsequently or modern comments of events in the past presenting the opinions of the authors of the first-hand sources)[7].

Historical data on tuberculosis in 18th–19th century are not numerous. Usually the disease is mentioned by foreign travellers visiting the Romanian principalities, or rarely in certain official documents. In laymen's terms, the disease was called *consumption*, while the use of *phthisis* or *tuberculosis* asserted in the 19th century, with the establishment of an official medical system.

The statistical yearbooks of Bucharest are a very important source of information regarding the characteristics of the population in 1880–1936. Such yearbooks were edited by the City Hall's Statistics Bureau[8]. The comprised data is varied and records evolve in time. Specific data included: weather conditions, situation of buildings and roads, population movements (including the new-borns and the dead, marriages, divorces), information on education or culture, electoral or sanitary data, finances, consumed foods, prices of products and services, number of sick patients. At the end of the 19th century the yearbooks provided limited information on the causes of death, but in 1931–1936 the information is more complex, including even separate data on TB mortality. This is also one of the reasons why the tables in this study or certain comparisons will refer only to certain periods.

The numbers in the yearbooks were completed with or verified against other publications, such as "Mişcarea populaţiunii din România" (Movement of the population in Romania) for 1885–1903, and "Anuarul Statistic al României" (Statistical Yearbook of Romania) for 1912–1940, published by the Central Institute of Statistics.

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4 Resnick &Niwayama 1995, 2462; Santos & Roberts 2001, 2006; Ortner 2003, 228–230, 235–242; Matos & Santos 2006; Spekker& al. 2012, 116; Masson & al. 2013, 1; Hershkovitz & al. 2015, 2–3.

5 Kelley &Micozzi 1984; Eyler& al. 1996.

6 Ortner 2003, 246; Santos & Roberts 2001, 2006; Aufderheide& Rodriguez-Martin 1998, 137.

7 Mitchell 2012, 310–318.

8 ASB 1938, V.

Rainer Osteological Collection completes the written documents with another kind of information. The collection mainly comprises approx. 6,800 skulls gathered by Professor Rainer in 1918–1942. About half of them have been identified. At present 2,061 of skulls are of males and 1,173 of females, plus 75 skulls of children[9]. The collection data base holds records of 805 individuals that died of tuberculosis in Bucharest.

Results

Historical sources

The first mentions of tuberculosis in historical sources donot mention its presence in Bucharest but in neighbouring areas. Thus Dimitrie Cantemir (Ruler of Moldavia, 1673–1723) is the first to mention in his writings that "consumption" as a long-term chronic disease. According to Cantemir's biographer, his second daughter suffered from TB[10]. F. J. Sulzer, a captain in the Habsburg army, mentions in his work *Geschichte des transalpinischen Daciens* from 1781 the incidence of phthisis in this area[11]. In the spring of 1785, Constandicel Lipscanul is mentioned to have died in Craiova and shortly afterwards a physician from the city is sent to verify whether the respective person had died of TB, so that his clothes wouldn't be sold[12]. The disease was also a cause for divorce in a nobleman's family in 1815, because the sick husband had hidden from his healthy wife the previous TB cases in his family[13].

The fiscal census of Bucharest in 1838 records 65,204 inhabitants based on the following criteria: address, number and name of family members and servants, tenants, ethnicity, age, civil status, social class, profession, vaccinations, place of birth, citizenship, disability and ownership of big animals. It appears that the data is not real, because only 309 chronic disease patients are recorded, of which one suffering from tuberculosis. At this population level, there were 38 physicians, 11 pharmacists and 13 midwives. In a report of the military hospital from the same year but regarding the year 1837, 25 TB patients are mentioned, of which 10 had died[14].

The first laws regarding TB are issued in the Kingdom of Romania at the end of the 19th century. Thus, the sanitary laws from 1885, 1898 and 1897 established special veterinary measures to fight the disease, such as examination of the meat and slaughtering the sick animals. In 1891 the "first regulation for infectious diseases" passes, establishing the norms regarding TB for both common people and physicians or veterinarians[15].

Dr Proca, the head of the bacteriology laboratory of Bucharest, wrote a paper on TB foci and established the identification criteria: high number of patients, simultaneous infections or at short time apart, persons of similar ages or professions or living in the same place are affected and represent a permanent source of infection[16].

Rainer Collection

Professor Rainer collected numerous osteological specimens to form his "Bone morpho-biology collection", amongst which 14 were diagnosed with Pott's disease, but have not been preserved to this day; these were parts of the spine, including thoracic and lumbar vertebrae[17].

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[9] Ion 2011, 24–32.
[10] Samarian 1938a, 297.
[11] Banu 1935, 168.
[12] Samarian 1938b: 405.
[13] Samarian 1938b: 406.
[14] Cernovodeanu&Vătămanu 1999, 121–125.
[15] Felix 1901, 153–154.
[16] Proca 1902, 6.
[17] Academia Română 1947: 70.

In the '70s, a study on the crania of persons who died of TB have compared the crania of persons with other causes of death, but no significant statistical results were conclusive to draw a relationship between this disease and the shape of the skull[18].

For Rainer Collection crania, the names, profession, the age of death, cause, date and place of death are known. Therefore, were identified 518 male crania and 287 female crania for which the recorded cause of death was TB. Most of the crania date to 1930–1939 when most of the crania in the collection were gathered (table 1).

Decade	**1910–1919**	**1920–1929**	**1930–1939**	**1940–1949**	**Unknown**	**Total**
Masculine	1	36	367	109	5	518
Feminine	0	25	202	57	3	287

Table 1. The numbers of individuals from Rainer Osteological Collection with TB recorded as cause of death (total number of skulls: 2061 males and 1173 females)

Regarding the age of death, most female and male individuals represented 20–29 and 30–49 age groups, but also 40–49 age group (table 2).

Ages	**10–19**	**20–29**	**30–39**	**40–49**	**50–59**	**60–69**	**70–79**	**80–89**	**Unknown**
Masculine	17	124	129	112	88	35	6	3	4
Feminine	17	91	93	42	18	16	2	2	6

Table 2. The number of individuals with TB on age groups

Even though at that time men and women had specific professions, most TB cases occurred among workers, but peasants are also well represented among males and housewives among females (table 3).

Masculine	*Unknown*	*Workers*	*Peasants*	*Intellectual professions*	*Beggars*	*Others*
Number	34	336	50	35	23	40
Feminine	*Unknown*	*Workers*	*Maids*	*Intellectual professions*	*Housewives*	*others*
Number	22	138	28	0	69	30

Table 3. The number individuals by professions

Regarding the place of birth, we noticed that individuals born in the rural area were double in numbers compared to individuals from the urban area, but in both cases, a significant number of individuals are from an unknown place of birth (table 4).

Birth place	**Unknown**	**Urban**	**Rural**
Masculine	139	110	269
Feminine	85	68	134

Table 4. The number of individuals by sexes and place of birth

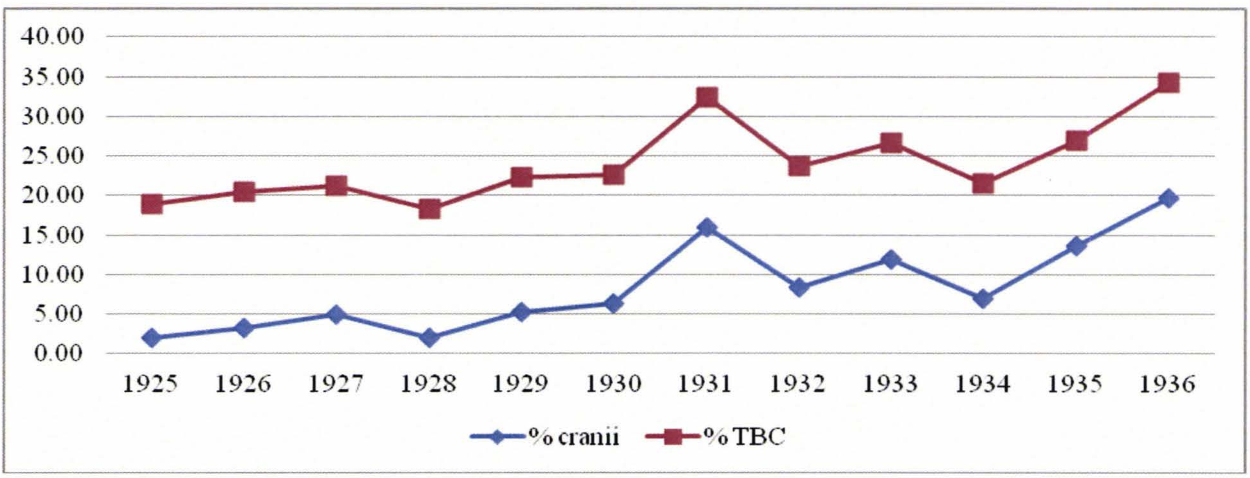
As variants, the pulmonary tuberculosis is the cause of death for over 90% of both sexes, against other forms of TB (table 5).

[18] Popovici et al. 1975: 7–13.

Cause of death	Masculine	Cause of death	Feminine
pulmonary TBC	480	pulmonary TBC	263
TBC + heart disease	4	TBC + heart disease	2
TBC + stomach disease	2	TBC + stomach disease	4
TBC + liver disease	1	TBC + psychic disease	8
TBC + lungs disease	7	TBC + infections	4
Meningeal TBC	5	TBC + others	6
TBC + general paralysis	8		
TBC + schizophrenia	3		
TBC + others	8		

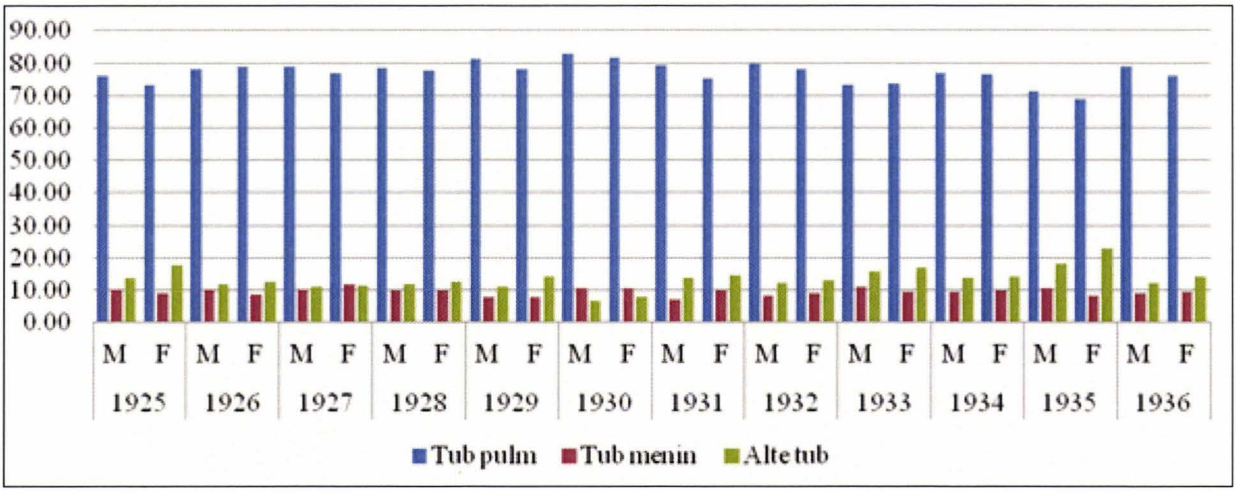
Table 5. The of number of individuals by sexes and cause of death

Compared to the official data in the statistical annuals, the crania of the individuals who died from tuberculosis found in the Rainer Collection provide a limited reflection of the reality of the era. The crania belonged to persons deceased in Bucharest and were collected from hospitals or morgues. The families wouldn't claim them or the Medical School would buy them for dissections, thus the skeletons came to be preserved at the Institute of Anthropology. It is not known of any intention of the collector, Dr Francisc Rainer, to select certain bodies, even though most of the individuals in the collection are born in rural areas, were infected with TB in Bucharest, pertained to the inferior social classes and practised professions that predisposed them to TB infection. The evolution of the percentage of crania with TB for 1925–1936 follows the same trend as the percentage of TB deaths in Bucharest: a higher number of crania in 1931 and 1936, when the higher number of deaths occurred (graph 1).

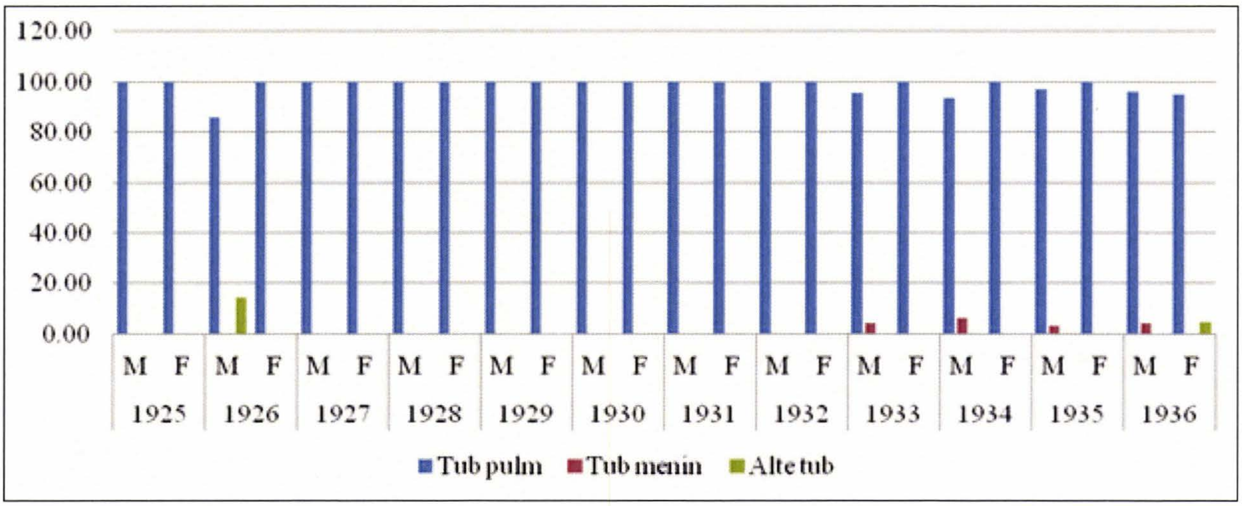


Graph 1. The evolution of skulls percentage from Rainer Collection (rhomb) versus the percentage of people died of tuberculosis in Bucharest (square)

Regarding the form of TB that caused the death of the individuals, the statistical yearbooks and Rainer Collection converge only on pulmonary tuberculosis as the cause of most deaths. In the statistical annuals for 1925–1936, pulmonary, meningeal and other forms of TB were recorded, while the crania provide evidence of other diseases in addition to the two forms of TB, with no direct link with the latter: schizophrenia, general palsy, epilepsy, cardiac or pulmonary diseases or of other organs (graphs 2 and 3).



Graph 2. Types of tuberculosis based on the statistical yearbooks data



Graph 3. Types of tuberculosis based on the Rainer Osteological Collection

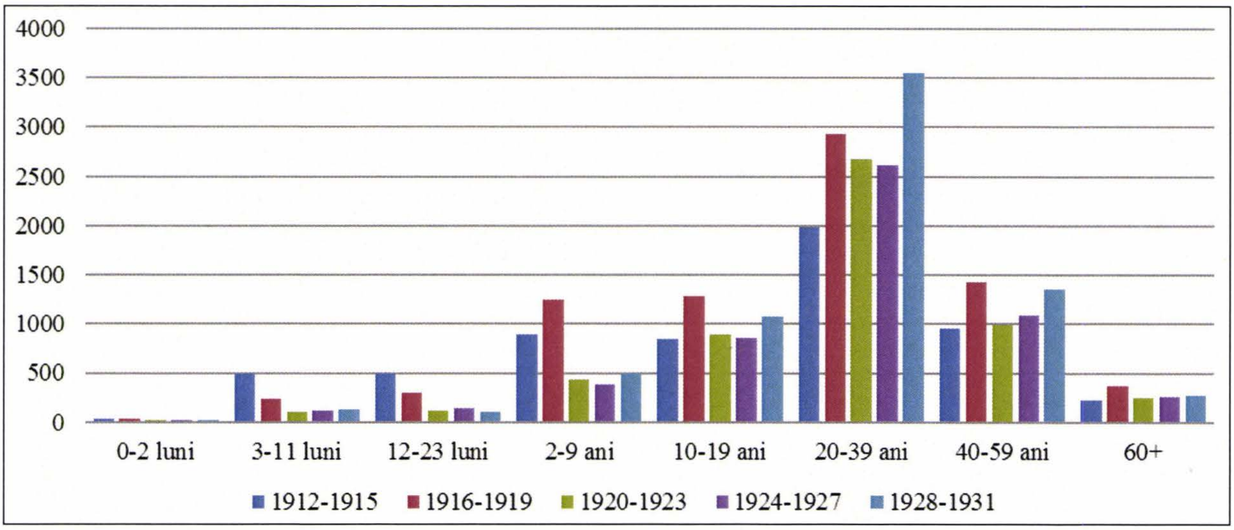
The ratio of males and females was calculated for the above-mentioned period: 1.43 average male ratio according to the statistical annuals for 1925–1926, and 3.02 male ratio in the Rainer Collection (table 6).

M/F	*SYA*	*ROC*
1925	1.47	7.00
1926	1.44	2.75
1927	1.41	2.43
1928	1.45	1.40
1929	1.37	2.25
1930	1.35	2.44
1931	1.47	3.24
1932	1.53	2.90
1933	1.35	2.41
1934	1.39	3.00
1935	1.27	3.13
1936	1.62	3.24

Table 6. Proportion masculine-feminine in statistical yearbooks for Bucharest (SYB) and Rainer Osteological Collection (ROC)

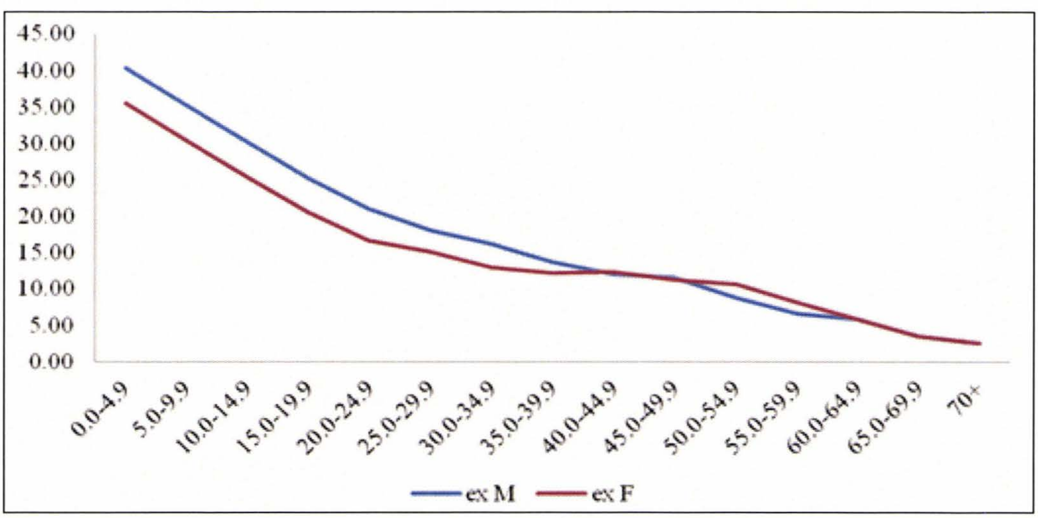
In the early 20th century, Dr Proca, who was a member in the "Bucharest Hygiene Committee", noticed that sex ratio in 1876–1901 was approximately 60% male and 40% female, which he explained by a higher incidence of alcoholism among men and "greater physical and moral fatigue". He also considered that higher mortality among men was due to "longer duration of TB". The disease lasted less for women and was favoured by sedentary lifestyle and motherhood. In Dr Proca's opinion, this caused male patients to grown in numbers, hence the higher mortality[19]. Approximately 30 years later, Dr Banu (professor at the Medical School) noticed that women are more affected by TB during their fertile years, up to 40 years old[20]. More men became sick than women, but women died sooner.

The above statements were verified in the statistical annuals and Rainer collection. More deaths occurred at the ages of 20 to 39, when women give birth to most children (ASB data for 1915–1931) than at earlier or later ages (graph 4).



Graph 4. Number of TB cases for both sexes and all ages 1912–1931, SYB

The demographic analysis of the crania with signs of TB[21] indicates for the 20–39 age group that: life expectancy for women is 3 years shorter on average, mortality curve is higher for females, and men outlive women by an average of 10% (graphs 5, 6, 7).

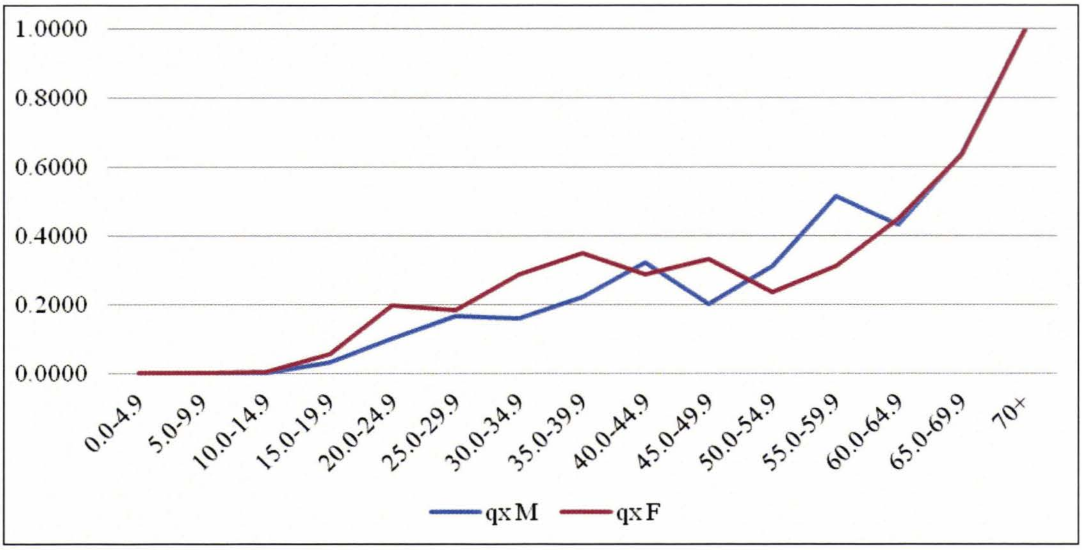


Graph 5. Life expentancy for males and females with TB from Rainer Collection

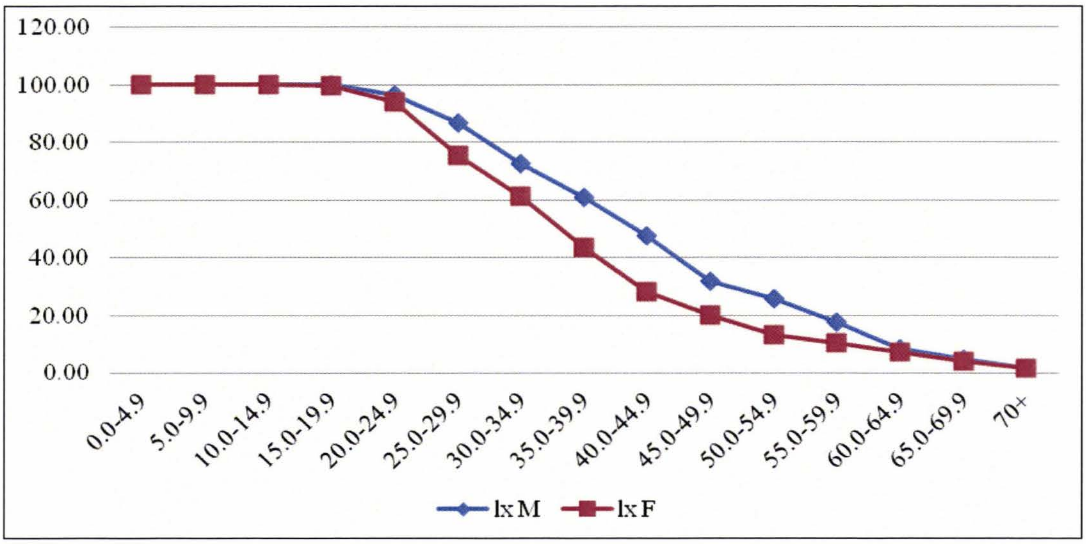
[19] Proca 1902: 16–21.

[20] Banu 1935: 193.

[21] Acsádi&Nemeskeri 1970; Ubelaker 1978: 95–96.



Graph 6. Curve of mortality for males and females from Rainer Collection



Graph 7. Curve of survival for males and females from Rainer Collection

In fact, the TB crania of women from the 20–39 age group represent 65% of the total number. All these results confirm the numbers in the statistical yearbooks or the observations of various physicians.

Discussions

To the above-mentioned cases proving the existence of the disease in nearby geographical areas we can add the observations and studies of the physicians from the end of the 19th century and early 20th century. Their notes focused on the population of Bucharest due to the city's larger number of inhabitants and better knowledge of their living conditions.

TB was and is still considered a disease of "poverty"[22]. Migration from villages to cities and overcrowding of the urban area facilitated the spread of the disease. For instance, from 1831 to 1930, the population of Bucharest increased from 58,794 inhabitants to 631,288[23]. Overcrowding was doubled by unsanitary living conditions, very low hygiene standards, insufficient water sources and

[22] Roberts &Buikstra 2003, 55.
[23] Millea 1933, 16.

absence of a sewage system. Drainage works started late in Bucharest, inț1880, involving paving and sewage works, regularization of Dâmbovița River and improvement of the quality of water supply to the city[24]. Dr Proca, in his study for 1899–1901, identified 110 streets (out of total 426 registered streets) with residences where 1,383 deaths occurred (out of a total 2,266 deaths). He explained that the respective buildings were unsanitary, humid, overcrowded, dark and unventilated[25].

Much of the responsibility for the spread of TB falls on the industrial city that emerged at that time in Europe and provided inhumane working conditions in polluted air, with more than 10 working hours a day and no breaks[26]. Bowden and McDiarmid[27] identified three categories of professions with a high risk of TB infection: unqualified jobs, jobs exposed to elevated pollution and activities that increase exposure to infection.

In the early 20th century, Dr Proca considered that the real TB foci were the shoemaker's shops, carpenter's shops, tailor' shops or ironworks shops, not necessarily due to the professions practised there but especially due to lack of hygiene. In 1898, 10,958 persons in 1,555 shops were examined and 163 were diagnosed with TB: 48 in shoemaker's shops, 43 in printing houses, 18 at the tobacco factory, 11 at the match factory, and 11 in tailor's shops[28]. For 1899–1901, most deaths, by profession, occurred among craftsmen and workers: 325 out of total 774; intellectual professions rank last. Most deaths occurred among shoemakers, carpenters, tailors and blacksmiths[29].

In 1915 another research was carried out on TB mortality by profession, for the previous 10 years, and the highest percentages (calculated against the number of works) were encountered among mechanics/electricians (18.63%), followed by typographers (14.04%), blacksmiths/locksmiths/tinsmiths (11.30%), stonemasons (10.00%) and carpenters/coopers/ wheelers (10%)[30].

In the statistical yearbooks of Bucharest, we could follow the percentages of TB deaths in 1875–1936 against the total number of deaths. Thus, for the 61 years span, we calculated an average of 15.66% with 11.25% low (in 1878) and 20.17% peak (in 1913), and average mortality rate (calculated as number of TB deaths against the total population of the city) was 0.3793% with 0.2014% low in 1935 and 0.5530% peak in 1888 (table 7).

Year	Deceased by TBC	Total no of deceased	Percentage (%)	Mortality(%)
1875	845	5835	14.48	0.4919
1876	830	4962	16.73	0.4741
1877	858	5833	14.71	0.4839
1878	848	7538	11.25	0.4774
1879	830	7120	11.66	0.4698
1880	749	6328	11.84	0.4245
1881	800	4860	16.46	0.4503
1882	725	5256	13.79	0.4066
1883	905	5767	15.69	0.5059
1884	873	5265	16.58	0.4854
1885	905	5482	16.51	0.5002
1886	895	5808	15.41	0.4920

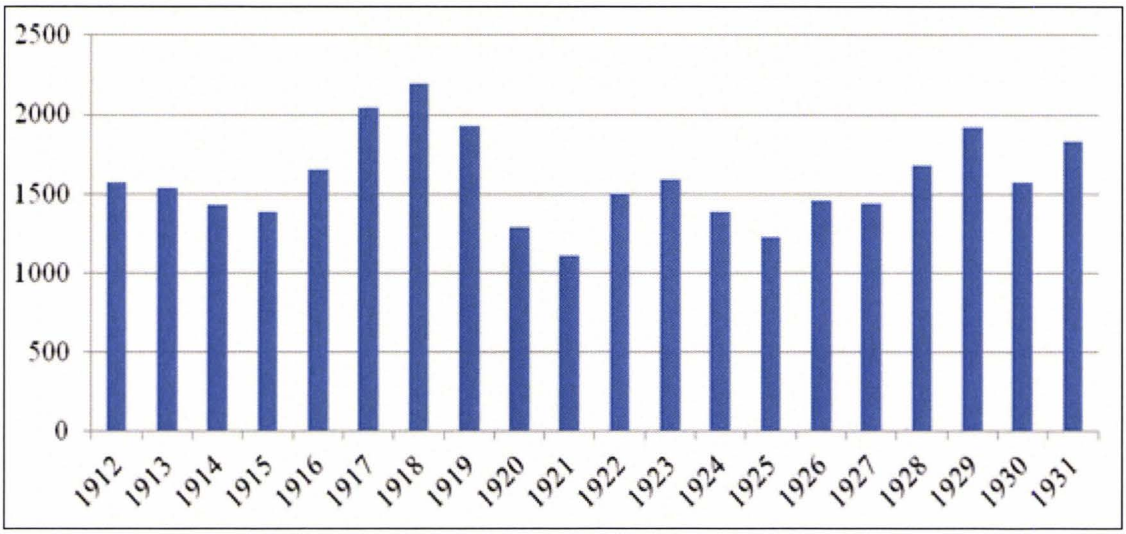
24 Millea 1933, 73.
25 Proca 1902: 24–26.
26 Cartwright&Biddiss 2006.
27 Bowden&McDiarmid 1994.
28 Proca 1902, 9.
29 Proca 1902, 22–23.
30 Banu 1933, 14.

Year	Deceased by TBC	Total no of deceased	Percentage (%)	Mortality(%)
1887	893	5800	15.40	0.4886
1888	1014	6317	16.05	0.5530
1889	865	5749	15.05	0.4689
1890	838	5779	14.50	0.4321
1891	803	6345	12.66	0.3948
1892	910	6512	13.97	0.4289
1893	832	6473	12.85	0.3752
1894	865	5978	14.47	0.3728
1895	1096	6053	18.11	0.4522
1896	1160	6665	17.40	0.4602
1897	841	6747	12.46	0.3204
1898	918	7071	12.98	0.3374
1899	990	7507	13.19	0.3510
1900	1039	6513	15.95	0.3617
1901	844	6766	12.47	0.2891
1902	1035	6576	15.74	0.3493
1903	1108	6526	16.98	0.3685
1904	1231	6611	18.62	0.4034
1905	1438	7184	20.02	0.4657
1906	1204	6574	18.31	0.3840
1907	1112	7416	14.99	0.3500
1908	1025	7105	14.43	0.3177
1909	1275	7870	16.20	0.3901
1910	1208	7553	15.99	0.3685
1911	1471	7845	18.75	0.4375
1912	1578	7943	19.87	0.4617
1913	1525	7561	20.17	0.4315
1914	1429	8176	17.48	0.3905
1915	1383	8296	16.67	0.3650
1916	1651	10557	15.64	0.4209
1917	2047	11448	17.88	0.5040
1918	2200	13631	16.14	0.5231
1919	1930	10307	18.73	0.4432
1920	1290	8927	14.45	0.2861
1921	1109	7555	14.68	0.2376
1922	1498	8484	17.66	0.3099
1923	1587	8819	18.00	0.3171
1924	1390	7856	17.69	0.2683
1925	1223	7265	16.83	0.2280
1926	1453	8392	17.31	0.2616
1927	1435	8774	16.36	0.2495
1928	1677	10356	16.19	0.2816
1929	1920	11277	17.03	0.3114

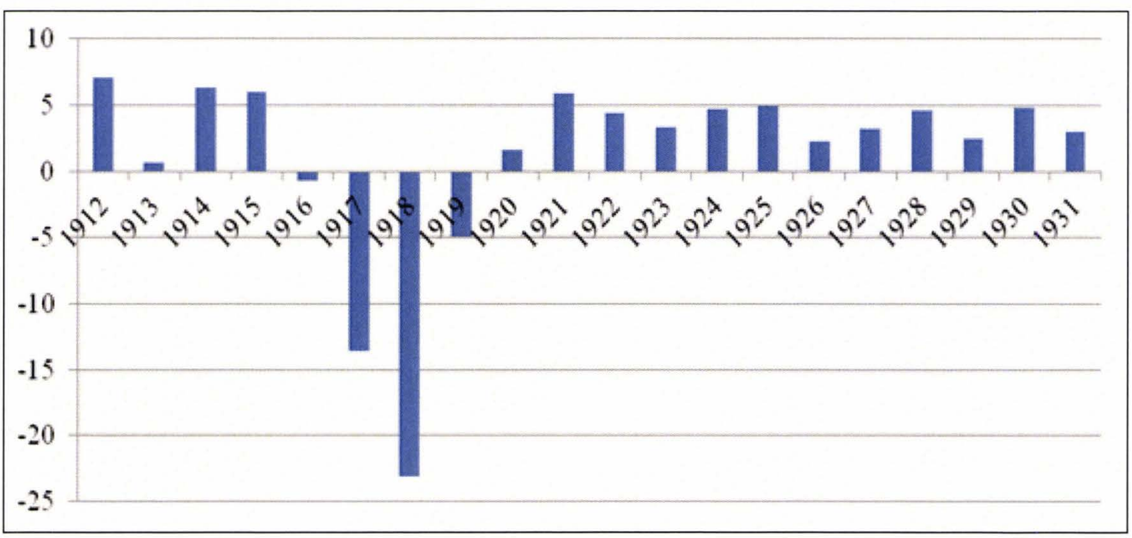
Year	Deceased by TBC	Total no of deceased	Percentage (%)	Mortality(%)
1930	1693	10434	16.23	0.2651
1931	1834	11160	16.43	0.2773
1932	1659	10871	15.26	0.2423
1933	1576	10647	14.80	0.2223
1934	1530	10483	14.60	0.2084
1935	1531	11441	13.38	0.2014
1936	1728	11901	14.52	0.2247

Table 7. Number of the deceased caused by TB in 1868–1936 for Bucharest (ASB 1931–1936: 12–15)

During World War I, TB mortality increased in the countries that directly participated in the battle, possibly due to malnutrition, precarious hygiene or overcrowding[31]. The same is found for Bucharest under the occupation of the Central Powers in 1916–1918, when TB deaths significantly increased: 2,047 in 1917 against 1,651 in 1916, 2,200 in 1918 and 1,930 in 1918. At the same time, the population's rate of natural increase was negative due to elevated mortality (graph 8 & 9).



Graph 8. Number of the deceased caused by TB in Bucharest (ASB)



Graph 9. Rate of natural increase for Bucharest (ASB)

[31] Banu 1933, 53.

Among other reasons, Bucharest was chosen as the capital of the Principality of Wallachia for its strategic position along the commercial road from the Danube to SE Transylvania, on the valleys of Argeş and Dâmboviţa Rivers, drawing many merchants from the Lower Danube basin to its fairs. Its geographical position also made it one of the seasonal transition areas of the animal herds going from the mountains to the Danube[32]. In the 15th–19th centuries, the city was permanently affected by Ottoman occupation and later on by Russian and Austrian occupation, which triggered long periods of political, social and economic instability, in addition to the direct military and social impact[33]. All these factors contributed in various proportions to the spread of the infectious diseases, and the negative impact on the quality of life predisposed the population in the area to contamination with such diseases.

Conclusions

A combination of almost all "classical" factors contributing to the spread of infectious diseases is also responsible for the spread of TB in medieval Bucharest, according to historical data. Climate changes, military invasions, city overcrowding, migration, poverty, elevated presence of animals have all contributed to lowering the quality of life and to the recrudescence of infectious disease epidemics at the end of the medieval age and in the modern age. Thus, following the military occupation of 1828–1829, one of the sources at that time recounted that *"cholera came to harvest what the plague had left behind"*[34].

Rainer osteological collection is the result of a random selection from lower social classes, but the osteological data is influenced by how TB causes skeletal lesions (such lesions appear only in 2% up to 5% of the cases of TB infections), by the difficulty in identifying such lesions at an incipient stage of bone reaction and by the post-mortem missing parts and destructions. On the other hand, the historical data in the studied area for the medieval and modern ages focus more on events than on the social dimension.

Though the quality of information is uneven, especially due to the structure of each source, it is still important to attest the presence of the disease in the studied area and period. Nevertheless, only a mix of sources can provide a picture closer to reality, because taken separately the sources give a subjective image of the incidence of TB in different periods. Table 2 indicates several common elements in all types of utilized sources, typical for the spreading pattern of infectious diseases in general and of TB in particular. The vast majority of individuals suffering from TB fall in the 14–49 age interval, women die at younger ages than men, mainly urban population is more affected, and *M. Tuberculosis* seems to the main agent in spreading the disease.

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[32] Constantinescu-Mirceşti 1976, 23.
[33] Iorga 1925.
[34] Iorga 1925: 145.

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DENTAL MORPHOMETRIC ANALYSIS OF MEDIEVAL AND EARLY MODERN ARTEFACTS FROM MUREŞ COUNTY, ROMANIA

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Keywords: dental morphology, morphometric analysis, anthropology, mandibular measurements

Abstract

Dental morphometric analysis is a quantitative investigation method that can be a useful resource in archaeology, due to the durability and stability of teeth. Present study aims to introduce a digital method in our region, as no previous research regarding dental morphometric analysis in archeology was found here. Human remains from three different locations were studied (Târgu Mureş - Liceul Bolyai, Jacodu, Sânvăsii) and grouped by location. Remains were dated from the 14th–17th centuries. Dental traits of 44 human remains from these regions were evaluated and a total number of 166 teeth and 44 mandibles were measured by 2D image analysis method. Teeth were captured in standard conditions and pictures were transferred in the Image Pro Insight software. Measurements were performed by a trained operator. Measurements included maximum crown diameters (mesio-distal, bucco-lingual and inciso-cervical), occlusal area, root lengths, ramus height and width, gonial angle and mandibular notch depth. Statistical tests were performed in order to see the differences between the three groups. Significant differences were found especially in mesiodistal crown diameter between the Bolyai group (14th century) and the two other groups (16th–17th centuries). Mandibular measurements also showed statistically significant differences between the groups. 2D image analysis method is a useful tool in archeology to study morphological features of teeth, maxillary and mandibular bones.

Introduction

Anthropology means the study of human beings and societies in the past and present. It is a generic term covering more than one area. We distinguish between two main groups: the field of science which examines the physical properties of death and living human populations and socio-cultural anthropology, focusing on the cultural development of the human race.

Teeth, as an integral part of human organism, are not exceptions from physical anthropology changes caused by biological evolution and way of living. As a main reason for the variability we can highlight the geographical separation and adaptation to the appropriate environment, natural selection, migration, population change, social impacts and different stress factors. Over the years, the body has to cope with a lot of stress effects and pathogenic diseases which can affect the soft tissues, bones and teeth as well. However, only the latter two can be studied on archaeological human remains, such as cysts, abscess, enamel hypoplasia, tooth abrasion, caries and periodontal disease associated with bone resorption[1].

In addition to pathological changes, size and morphological variations may also appear which are more typical in certain communities. Regarding to this, the superior molars are the most exposed teeth to morphological variations. Since the first description by György Carabelli in 1842,[2] the etiology of the additional cusp has not been clarified. Both genetic and exogenous factors are responsible in terms for their occurrence. Most researchers agree that its phenotypic appearance is genetically determined, they assume the role of the dominant gene in the background. The appearance of the Carabelli trait is not uniform. Dahlberg[3] distinguishes between seven degrees of size and expressiveness in his scientific studies. Depending on the cause, the literature separates the concept of abrasion, attrition and erosion as pathological changes[4].

During life, teeth are exposed to physical extrinsic impacts which causes teeth abrasion. Harmful habits, as chewing of various objects and the unsuitable use of the dentition, as a working tool can lead to local or generalized abrasion of the tooth[5].

Dental attrition is a type of tooth wear caused by tooth-tooth contact, resulting in loss of tooth tissue, usually starting at the incisal or occlusal surfaces. Tooth wear is a physiological process and is commonly seen as a normal part of aging.

Attrition can be increased by abrasive food consumption, bruxism associated with anxiety conditions, and in the absence of distal support of grinding teeth. In severe cases, an inflammatory tooth disease may occur due to frequent food retention[6].

Dental erosion is an irreversible tooth structure loss caused by chemical attacks. The frequency of its incidence increases as salivary buffer capacity decreases or when gastroesophageal reflux disease is present[7].

In the triggering mechanism, the demineralization of the tooth surface contacting the acids is associated with abrasion or attrition. The frequency of this incidence increases as salivary buffer capacity decreases or when gastroesophageal reflux disease is present[8]. The Huszár Scale (1976)[9] can be used to track the tooth wear. A total of six grades express the involvement of the teeth (sine abrasione, abrasio superficialis I, abrasio superficialis II, abrasio media, abrasio profunda compensata, abrasio profunda incompensata)[10].

Present study aims to introduce a digital method in our region, as no previous research regarding dental morphometric analysis in archeology was found here and to ascertain if there is any evidence for dental morphological differences between three settlements in Mures county.

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[1] Bodzsár, Zsákai 2013, 113.
[2] Carabelli 1844.
[3] Dahlberg 1971; Budai 2007.
[4] Mavrodisz et al. 2007.
[5] Fazekas 2006.
[6] Fazekas 2006.
[7] Fazekas 2006.
[8] Fazekas 2006.
[9] Wetselaar 2016.
[10] Budai 2007, 3, 38, 18–19, 40–42.

Methods

Our research team formed by three dental students and a university teacher from the University of Medicine and Pharmacy Tîrgu Mureş, Faculty of Dentistry with collaboration of the Mureş County Museum examined individually 166 teeth from 44 artefacts grouped in three different locations: Târgu Mureş (Liceul Bolyai)[11], Jacodu[12] and Sânvăsii[13]. The identification of teeth was based on the description of typical morphological characteristics and uncommon variations of dental anatomy literature. If the archeological artefact contained not only teeth but also mandibular or maxillar bone, the teeth were inserted into the alveolar process to check the pertinence of match. Another important phase was the suiting of missing and broken parts of human skulls with heated silicone wich makes possible to practise non-invasive reconstruction. Before reinsertion each tooth was individually captured from all possible aspects. Photographs were made using a photo tent, scattered light, Nikon D3100 body, macro lens (90 mm, 1:1 ratio) and a metal scale/mm paper for digital calibration. After the quality improvement of pictures, the Image – Pro Insight software was used for digital 2D image analysis and measurements.

Not all of teeth were suitable for measurements. Those teeth which presented massive destruction of crown, massive dental attrition (in some cases were so extensive that the pulp chamber presented opening), post mortem trauma or unfinished apexification and primary teeth were excluded.

The next parameters were measured (Figure 1):

- Length of tooth – sum of length of tooth and length of crown
- Length of crown – between crest of curvature at cementoenamel junction and incisal edge/ buccal cusps
- Length of root – between apex and crest of curvature at crown cervix
- Mesiodistal diameter of crown – between crest of curvature on mesial (mesial contact area) and distal surfaces (distal contact area)
- Mesiodistal diameter of crown at cervix – between junction of crown and root on mesial and distal surfaces
- Mesiodistal diameter of crown at occlusal surface – between crest of curvature on mesial (mesial contact area) and distal surfaces (distal contact area) from occlusal view
- Vestibulo-oral diameter of crown – between junction of crown and root on vestibular and oral surfaces
- Vestibulo-oral diameter of crown at occlusal surface – between the most pronounced vestibular and oral bend from occlusal view

In case of mandibular artefacts (Figure 2) we measured the next values:

- Mandibular notch depth – deepest distance between the mandibular notch and straight line that link the condyle and coronoid process
- Ramus width – value of ramus width measured under the mandibular notch
- Ramus length – length of ramus between angle and condyle
- Gonial angle (1) – measured direct at angle without the extension of straight lines
- Gonial angle (2) – measured at angle with the extension of straight lines between Go – Me and Go – Posterior part of ramus.

[11] SzOkl 1872–1934.
[12] SzOkl 1872–1934.
[13] SzOkl 1872–1934.

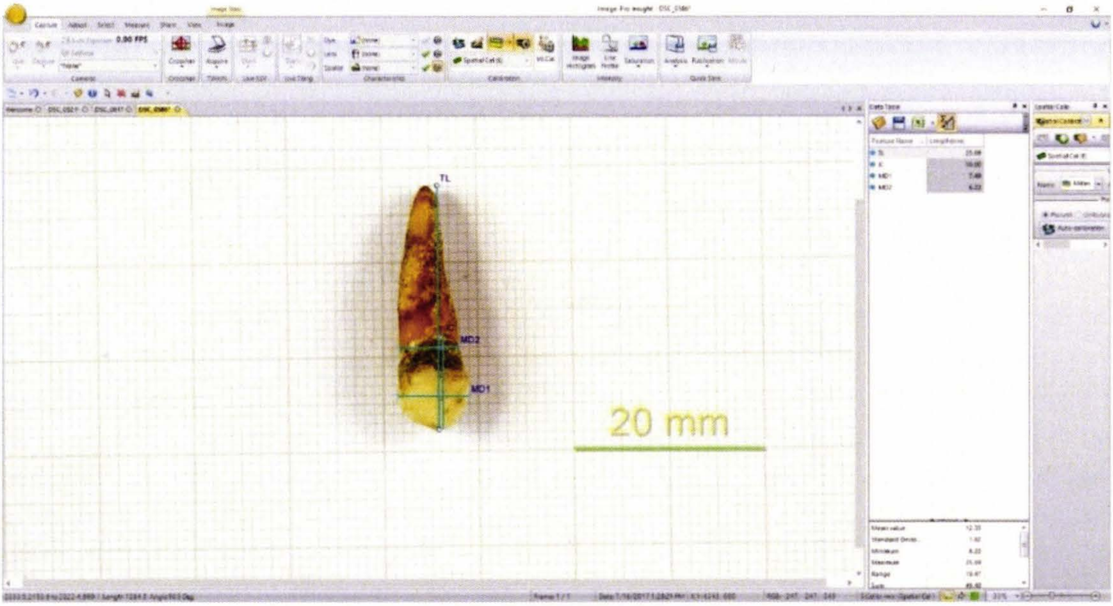

Figure 1. The Image-Pro Insight 2D image analysis and measuring software interface - Canine tooth vestibular parameters measurement after calibration

Results

The comparison of the mandibular measurements showed significant differences at ramus length, left ramus width and right notch depth. At all of three parameters the highest values belonged to Târgu Mureș – Bolyai. At above-mentioned ramus length Bolyai presented statistically significant higher values compared with Jacodu ($p=0.01$) and Sânvăsi ($p=0.02$). In case of left ramus width ($p=0.02$) and right notch depth ($p=0.01$) the statistically significant advantage of Bolyai were measurable only in comparison with Jacodu.

Figure 2. Mandible – lateral view – Târgu Mureș – Bolyai

At dental measurements the situation is more complex (Table I, II, III): the mesiodistal diameter of crowns in Târgu Mureș – Bolyai revealed statistically significant differences in case of upper central incisors compared with Sânvăsii ($p=0.01$) and Jacodu ($p=0.003$), lower central incisors compared with Jacodu ($p=0.003$), upper lateral incisors compared with Jacodu ($p=0.005$), upper second premolars compared with Sânvăsii ($p=0.002$). In case of the lower and upper first molars (*p=0.003*), upper second molars (*p=0.01*) Jacodu showed statistically higher values compared with Târgu Mureș – Bolyai. Sânvăsii presented significantly higher values in upper lateral incisors compared with Jacodu (*p=0.03*) lower central incisors compared with Jacodu (*p=0.008*).

The mesiodistal diameter of crown at cervix in Târgu Mureș – Bolyai showed significantly higher values in upper first premolars compared with Sânvăsii (*p=0.006*). The upper first molars in Jacodu compared with Bolyai (*p=0.003*) and lower lateral incisor in Sânvăsii compared with Bolyai (*p=0.003*) presented significant differences.

In case of vestibulo-oral diameters of crowns from occlusal view in lower first premolars in Bolyai presented significantly higher values compared with Sânvăsii (*p=0.01*). In upper first molars in Târgu Mureș – Bolyai compared with Sânvăsii (*p=0.0001*) and Jacodu compared with Sânvăsii (*p=0.04*) were also statistically significant differences revealed.

	Bolyai (mean ± SD)				
	MD	MDcerv	VO	C	R
S1	8.9±2.92	6.5±0.54	8.28±0.92	9.92±1.29	11.5± 1.53
S2	6.72±0.35	5.26±0.47	7.65±0.07	8.72±0.91	13.4±0.42
S3	7.5±0.18	5.88±0.49	9.0285±0.45	9.3±1.7	12.86±2.5
S4	6.85±0.28	4.83±0.26	9.1±0.85	7.21±0.47	11.55±2.79
S5	6.5±0.21	4.66±0.33	9.28±0.7	7.02±0.4	11.32±2.78
S6	10.09±0.8	7.47±0.92	11.33±0.67	6.85±0.58	12.02±0.7
S7	9.71±0.7	7.93±0.97	11.68±1.34	7.16±0.4	10.6
I1	5.49±0.3	3.53±0.43	6.25±0.69	8.58±1.11	13.3±1.43
I2	5.82±0.36	3.87±0.34	6.69±0.47	8.31±0.98	14.07±1.08
I3	6.51±0.25	5.33±0.53	8.18±0.57	9.74±1.54	12.88±0.37
I4	6.61±0.33	5.03±0.23	8.17±0.66	7.33±1.01	12.3±2.9
I5	7.19±1.14	5.16±0.9	8.27±0.65	6.32±1.08	13.38±0.69
I6	10.38±0.65	8.84±0.51	10.39±0.51	6.18±0.82	10.92±0.34
I7	10.25±0.66	9.11±0.52	9.97±0.80	6.55±1.002	11.7

Table I. Dental measurements in Bolyai group

	Sânvăsii (mean ± SD)				
	MD	MDcerv	VO	C	R
S1	8.07±0.4	5.92±0.25		10.58±0.27	12.31±0.38
S2	6.65±0.69	4.96±0.73		9.35±0.19	10.06±1.41
S3	7.51±0.04	5.40±0.12		8.56±2.1	16.88±3.71
S4	6.26±0.31	4.46±0.06	8.01±0.23	7.53±0.45	
S5	5.53±0.15	4.76±0.74	8.23±0.4	7.43±1.8	14.93
S6	11.27±1.01	7.35	10.14±0.50	6.90±0.36	14.30±2.22
S7	9.11	6.96	10.14±0.57	6.45±0.45	
I1	5.42±0.13	3.84±0.17		8.84±1.44	11.62±1.7
I2	5.61±0.44	4.41±0.32		7.31±1.17	12.4±1.18
I3	6.74±0.55		8.26	8.39±1.34	13.26±0.28
I4	6.52±0.36	4.95±0.04	6.90±0.93	6.95±1.18	11.44±0.89
I5	6.62±0.28	4.82±0.24	7.76±1.20	6.21±1.03	
I6	10.8	9.29	10.09±0.58	6.51±1.31	13.16
I7	9.44	8.69	9.9275±0.68	5.69±1.002	

Table II. Dental measurements in Sanvasii group

	Jacodu (mean ± SD)				
	MD	MDcerv.	VO	C	R
S1	7.84±0.45	5.39±0.17		8.31±2.24	11.53±0.47
S2	5.28±0.73	4.0333±0.87		8.35±0.30	11.5±2.26
S3	7.40±0.24	5.66±0.3		8.14±1.89	13.1±4.51
S4	6.94±0.62	5.62	8.69±0.23	8.15±0.1	13.16
S5	6.1966±0.43	4.40±0.56	7.80±1.13	6.98±0.1	15.7
S6	11.38±0.19	8.40±0.45	10.99±0.26	6.68±1.44	14.11±1.4883
S7	9.41±0.69	7.5	10.29±0.17	6.76±0.38	12.51±1.7112
I1	5.011±0.2	3.71±0.52		8.49±0.74	
I2	5.48±0.26	4.27±0.31		8.33±1.18	
I3	6.7875±0.86			9.8375±1.007	
I4	6.78±0.38	4.68	6.32±0.09	7.34±1.09	15.1±1.6122
I5	7.16±0.45		7.93±0.04	6.55±0.98	
I6	11.57±0.71	9.70	10.1±0.49	6.84±1.36	14.7±0.2260
I7	11.34±0.7	9.7±1.83	10.22±0.93	5.9122±0.84	13.72±0.9078

Table III. Dental measurements in Jacodu group

Five Carabelli cusps were identified on the human remains: two were grade 3, two grade 2 and one grade 1 after Dahlberg's classification. This morphological variation has a prevalence of 22.22% in case of Târgu Mureş – Bolyai group and 25% in case of Sânvăsii artefacts.

Different abrasion types were present at 69.90% of the human remains found in the archaeological sites of Târgu Mureş, Sânvăsii and Jacodu.

Figure 3.

Discussion

The overarching goal of this study was to ascertain if there is any evidence for dental morphological differences between three settlements (Târgu Mureş – Bolyai, Jacodu and Sânvăsii) from Medieval and Early Modern ages in 30 km circle from the center of Târgu Mureş. The uniqueness of our research is that there is no similar investigation in our region. The measurement of the different parameters and identification of different variations were based on the scientific literature[14].

The fact that the number and quality of artefacts was limited makes harder the evaluation of results and drawing far-reaching conclusions. At mandibular measurements from 44 artefacts only 25 were suitable for analysis and presented minimum one intact ramus. With bilateral measurements the number of data ascended to 38. It is important to note that it is present a difference

[14] Nelson, Weeler 2010, 10–18.

between the two sides but in spite of all these, the results show unanimously that the mandibular artefacts from Târgu Mureș – Bolyai are more pronounced, robust. This fact can serve for base of different anthropological and historical interpretations: above-mentioned settlement was the only with urban area from all of three that means presumably particularistic nutrition and intensified population change.

At the level of dental measurements the dominance of Târgu Mureș – Bolyai is no more present. The statistically significant results are fragmented mostly around teeth groups: much pronounced incisives at Bolyai and Sânvăsii, premolars at Bolyai and molars at Jacodu.

A possible explanation for statistically significant changes at the levels of mandibula and teeth can be that dental characteristics (size, shape, presence, cusps, size of dentak arches) are genetically determined. According to the scientific literature these characteristics can change due to natural selection and genetic changes [2]. In Table IV the mean values of mandibular measurements of researched graves and historical ages according to the scientific literature are shown[15].

	Ramus length	**Ramus width**	**Notch depth**
B	**60,14 µm**	**42,92 µm**	**14,21 µm**
N	**54,18 µm**	**35,75 µm**	**14,4 µm**
Z	**56,53 µm**	**35,22 µm**	**11,82 µm**
Avar age	58,78 µm	39,28 µm	13,37 µm
Conquest period	57,42 µm	38,30 µm	12,07 µm
Arpadian age	63,93 µm	31,71 µm	13,50 µm

Table IV. Mandibular measurements[16]

Periodontitis is an inflammatory disease that affects the supporting hard and soft tissues around the teeth. We identified 10 cases of this illness that manifested with bone loss, furcation defect and supra- and subgingival calculus: 5 artifacts from Bolyai, 3 from Sânvăsii and 2 from Jacodu. Connection between periodontitis and several pathological changes on the skeletons were present (for ex. cribra orbitalia, porotic hiperostosis, etc. – Bolyai cemetery).

According to research among contemporary populations, the incidence of hard tissue loss in teeth, caused by non-decayed lesions is 97%[17]. The severity of this lesion at group Târgu Mureș – Bolyai is remarkable: at some artefacts the abrasion level was irreversible, opened pulp chambers were detected (Figure 3–9). This fact can be in correlation with a possible higher age, when the secunder dentin growth can no longer keep up with tooth consumption. It may be the market town effect where the teeth were exposed to less intense stress due to a one-sided, more refined, less fibrous, hard-to-eat

Figure 4. Târgu Mureș – Bolyai skull – lateral view-Pathological lesions; Tooth wear (AM, AP, API) with bone resorption, III. degree furcation lesion and a periapical process associated with abscession

[15] Budai 2007.
[16] Budai 2007.
[17] Sucheta et al. 2014.

diet. It is also noteworthy that the molars from Bolyai group are in a less severe phase than the artefacts of the other two archaeological sites.

For the future we attend to complete our study with the examination of further morphology variations, attrition, epidemiology data based on the evaluation of dental caries and analysis of calculus to collect data about nutrition and to find any correlation between stature and metabolic diseases, or periodontitis and chronic diseases.

Conclusion

The interdisciplinary study of archaeological artifacts from the region that is provided by Mureş County Museum can serve with new data regarding to anatomy, health statue and lifestyle. The 2D image analysis method is an applicable and useful tool in analysis of morphological features of teeth and mandibular bones. For far-reaching conclusions and exclusion of possibility of false results a higher quantity and quality of artifacts are necessary.

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Figure legends

Figure 1: Image Pro Insight 2D program – Canine tooth vestibular parameters measurement after calibration

Figure 2: Târgu Mureş – Bolyai mandible – lateral view

Figure 5.

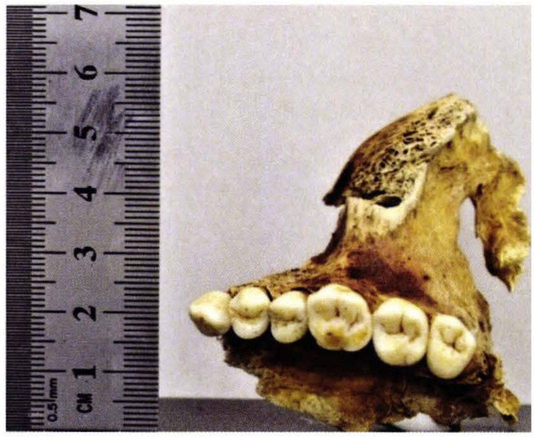

Figure 6.

Figure 7.

Figure 8.

Figure 9.

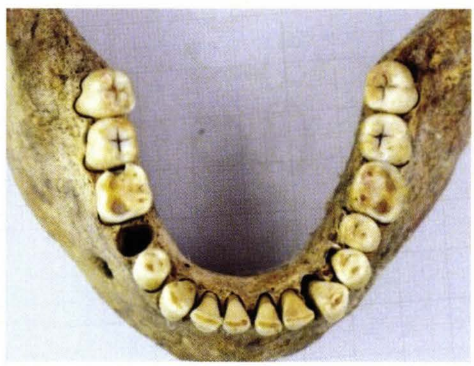

Figure 10.

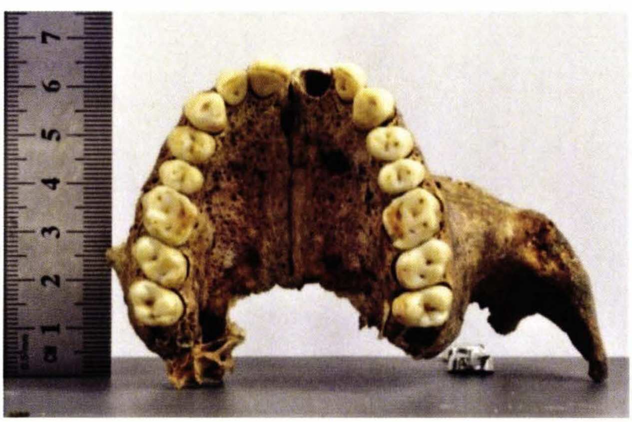

Figure 11.

Figure 12.

Figure 13a.

Figure 13b.

Figure 14.

Figure 15.

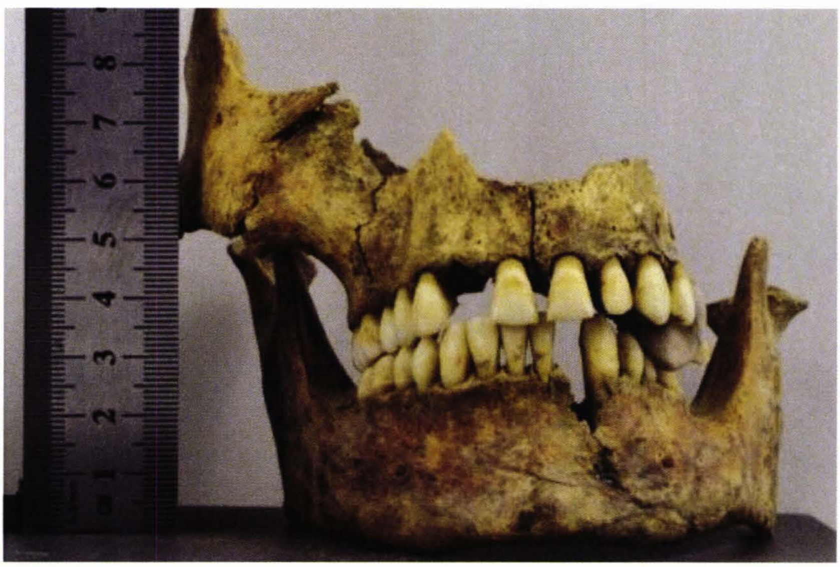

Figure 16.

VARIETIES AND CHARACTERISTICS OF STERNAL DEVELOPMENTAL ANOMALIES IN HUMAN OSTEOARCHAEOLOGICAL REMAINS

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Abstract

Developmental anomalies of the skeleton may also affect the sternum. They can appear in many forms from minor anomalies (e.g. foramen sterni, variations of processus xyphoideus, minor clefts, ankyloses, under- or overdevelopment of certain sternal segments) to more serious deformities (e.g. sternal aplasia, pectus carinatum, pectus excavatum).

The aim of this paper is to introduce main sternal developmental anomalies using examples from contemporary and archaeological populations, to show the morphological variety of these health issues, to outline possible co-occurrences with other anomalies and connections to syndromes, and also to give an account of the genetic or developmental background of these deformities. Also, pectus carinatum (a major sternal deformity) will be discussed from viewpoints of paleopathology and medical history, with reference to osteoarchaeological cases from the Southern Great Plain.

Introduction

The adult sternum can be divided into three sections, the manubrium, the mesosternum and the xiphoid process. Development of these parts begins during the fifth-sixth gestinational week[1]. During the sixth to ninth gestational week the two sternal cartilage migrate medially towards each other and fuse, forming a single cartilaginous rod by week ten[2].

The sternum develops from single manubrial and xiphoid centers, and single or paired mesosternal segments[3]. Sometimes the manubrium may develop from two or three centers, but this happens independent of the sternal body. In the examination of Delgado et al.[4] the prevalence of single manubrial ossification centers was 88%, and that of two or three manubrial ossification centers was 12% altogether. More than one manubrial ossification centers were correlated to younger age. The first mesosternal segment develops from single ossification centers in 85% of the cases.

Ossification of the manubrium and the first mesosternal segment occurs in the fifth or sixth intrauterine month. The remaining bodies ossify during the sixth, seventh or eighth month. The lowermost segment and the xiphoid ossify after birth[5]. Medial fusion of the paired mesosternal

[1] Barnes, 1994; van der Merwe et al., 2013.
[2] Barnes, 1994; van der Merwe et al., 2013.
[3] Steiner et al., 1976.
[4] Delgado et al. 2014.
[5] Steiner et al., 1976.

segments occurs before or soon after birth. Transverse fusion of the mesosternal segments occurs about the age of 20–25[6].

Materials and methods

To investigate developmental defects, osteoarcheological samples were obtained from the osteological collection of the Department of Biological Anthropology, University of Szeged, Hungary. The specimens were taken from different historical periods. Investigation of the bone collection was carried out mainly using macromorphological methods.

Results

1. Episternal (suprasternal) ossicles and episternal tubercle

Episternal (suprasternal) ossicles and tubercles are found above the posterior margin of the manubrium. In three dimensions, these ossicles are quadrilateral pyramids with bases that articulate with the manubrium[7]. Suprasternal tubercle *(Figure 1)* forms when a suprasternal ossicle fuses with manubrium[8]. They range from 2 to 15 mm in diameter. These classify as normal variants of the sternal morphology. They derive from supernumerary ossification centers and are usually seen in less than 10% of the population (1–7%[9]; 4%[10]). These ossicles may be unilateral or bilateral. Paired ossicles are more frequent than single ones[11], but Turkay and colleagues[12] found 1.8% unilateral and 1.2% bilateral episternal bones. Cobb[13] found separate or fused episternal ossicle in 6.8% of adult Caucasians and in 2.2% of adult Afro-Americans.

2. Fusions, non-fusions

2.1. Manubriosternal fusion

The manubrium fuses with the mesosternum usually above 40 years[14], or 50 years of age[15]. The time of fusion may depend on race, geographic region, climate, sex, diet, heredity, etc.[16], but before 40 years of age it only takes place because of developmental issues. Defects may occurs when the fibrous lamina fails to develop between the developing manubrium and the first sternebra of the mesosternum[17]. Manubriosternal fusion *(Figure 2)* can be partial or complete. According to Yekeler and colleagues[18], the frequency of manubriosternal fusion is 10%. Turkay and colleagues[19] found fusion in 22.4%, and partial fusion in 13% of the cases. Manubriosternal fusion in older age groups due to degeneration can be associated with bridging osteophytes. Inflammatory arthritis (especially ankylosing spondylitis) can lead to similar fusion of the manubriosternal joint[20].

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6 Steiner et al., 1976.
7 Cobb, 1937.
8 Duraikannu et al., 2016.
9 Cobbs, 1937.
10 Yekeler, 2006.
11 Cobb, 1937; Yekeler, 2006.
12 Turkay et al., 2017.
13 Cobb 1937.
14 Tailor et al., 2013.
15 Chandrakanth et al., 2015.
16 Tailor et al., 2013.
17 Barnes, 2012.
18 Yekeler et al., 2006.
19 Turkay et al., 2011.
20 Duraikannu et al., 2016.

2.2. Sternoxiphoidal fusion

Sternoxiphoidal fusion *(Figure 3)* can be partial or complete. The frequency of sternoxiphoidal fusion is 32.4% according to Yekeler et al. (2006), and 30.5% according to Turkay et al. (2017). The fusion of the mesosternum and the xiphoid process starts above 30 years of age (Tailor et al., 2013).

2.3. Total fusion of the sternum

Sometimes the manubriosternal and sternoxiphoidal fusion can occur simultaneously *(Figure 4)*.

2.4. Non-fusion of sternal segments

Fusion of sternal body segments is usually complete by 25 years of age. But non-fusion of sternal body segments can occur in older age groups. This defect develops when the fibrous lamina is misplaced between the sternebrae[21].

3. Bifid sternum, sternal cleft

Sternal cleft or bifid sternum is a rare abnormality of the anterior chest wall. In this condition the two halves of the sternum are separated. Sternal cleft results from failure of fusion of the two lateral mesoderm bars of the sternum by the eighth gestational week. The extent of the lesion ranges from a complete or partial linear fissure to a larger vertical hiatus within the sternum. The larger defects can be associated with complex syndromes[22].

Depending on its orientation, the defect can be superior (cranial clefting), inferior (caudal clefting) or complete[23]. Yekeler and colleagues[24] determined manubrial cleft in 0.6% and sternal cleft in 0.8% of patients, but Macaluso and colleagues[25] did not observe any sternal cleft during their sternal examinations. Sternal cleft may be a solitary condition (27%) or associated with other abnormalities (73%)[26].

3.1. Caudal clefting of the sternum

This anomaly results from delayed caudal fusion of the lateral mesosderm bars of the sternum. Usually, the delay is minor with only a cleft or fissure *(Figure 5/a, Figure 5/b)* at the caudal rim of the last sternebra[27].

3.2. Cranial clefting of the sternum

The reason of this anomaly is a failure of fusion at the cranial ends of the lateral mesoderm bars of the sternum by the eighth gestational week. This rare developmental defect may be associated with other congenital anomalies that may or may not be compatible with life[28].

4. Mesosternum shape variation

The shape of the manubrium and the mesosternum depends on the number and shape of ossification centers. Single manubrial ossification center was seen in 88% of the cases, and two or

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[21] Barnes, 2012.

[22] Kabiri et al., 2011; Duraikannu et al., 2016.

[23] Engum, 2008; Dumitrescu et al., 2017.

[24] Yekeler et al., 2006.

[25] Macaluso et al., 2014.

[26] Ramdial et al., 2016.

[27] Barnes, 2012.

[28] Kabiri et al., 2011.

three centers were seen in 12% of the cases in the investigation of Delgado and colleagues[29]. The first and second mesosternal sternebrae develop from single ossification centers, while the last two segments usually develop from two ossification centers[30]. Delgado and colleagues[31] did not found ossification center in the fourth segment in 38% of patients. Delayed development or lack of different ossification centers lead to a wide variation in shape of certain sternal segments or the complete mesosternum. The body of the sternum may have three different shapes *(Figure 6)*, longitudinal oval, flat, and "O" shape[32]. The flat shape is the most common shape of the sternum (68%), the longitudinal oval shape is the second most common, and the O shape is the least common shape variation[33].

5. Sternal foramen

Sternal foramen (SF) usually occurs from incomplete fusion of a pair of sternebrae[34]. Sternal foramen may be found in the manubrium, the sternal body or the xiphoid process.

5.1. SF on the manubrium

SF rarely occurs in the manubrium[35]. It may manifest as a little foramen in the middle of the manubrium[36].

5.2. SF on the sternal body

Mesosternal foramina are usually located in the caudal parts of the sternal body. This formation results from incomplete fusion of the sternal ossification centers[37]. The shape of SF is oval or circular, the size ranges between 3 and 16 mm[38]. SF is a relatively common minor developmental defect, but the frequency reported in the literature varies heavily between 3.1% and 57.7%[39]. Mesosternal SFs are are usually asymptomatic, but their presence can cause complications during sternal puncture.

5.3. SF on the xiphoid process

The prevalence of xiphoid foramen is similar to that of the mesosternal foramen. This defect can be single or double. In the investigation of Yekeler and colleagues[40] the average frequency was 27.4%, and the most common type was single foramen.

6. Major chest wall anomalies: pectus excavatum, pectus carinatum

Pectus deformities in various forms affect about 1% of the population. Boys are four times more frequently affected than girls[41].

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[29] Delgado et al., 2014.
[30] Barnes, 2012.
[31] Delgado et al., 2014
[32] Duraikannu et al., 2016.
[33] Bayaroğullari et al., 2014.
[34] Duraikannu et al., 2016.
[35] Cooper et al., 1988.
[36] Barnes, 2012.
[37] Paraskevas et al., 2016.
[38] Babinski et al., 2015.
[39] Babinski et al., 2015; Kirum et al., 2017; Paraskevas et al., 2016; Turkay et al., 2017; Yekeler et al., 2006.
[40] Yekeler et al., 2006.
[41] Williams et al., 2003.

6.1. Pectus excavatum

Pectus excavatum, also known as funnel chest, is the most common congenital deformity of the sternum. The anomaly may be present between one in 400 and one in 1000 live births[42]. Pectus excavatum is a depression of the anterior chest wall of variable extent that may be mild, moderate, or severe[43].

6.2. Pectus carinatum

Pectus carinatum *(Figure 7)* is less common than pectus excavatum[44]. Like pectus excavatum deformities, pectus carinatum affect boys more frequently than girls, at a rate approx. 3:1. Familial aggregation is found in about 25% of the case histories[45].

Summary

There is a wide variety of congenital defects and pathological abnormalities in the sternum. This paper describes some minor and serious congenital anomalies in this region. In general, the prevalence of sternal defects is low, but the less severe forms may appear more often (e. g.: sternal foramen). Prevalence, sex ratio and sidedness observed in our investigations were usually similar to literature data.

Acknowledgement

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[42] Cerswick et al., 2006.
[43] Goretsky et al., 2004.
[44] Williams et al., 2003.
[45] Williams et al., 2003.

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Figure legends

Figure 1: Suprasternal tubercle, Algyő–258. kútkörzet, gr. no. 34.

Figure 2: Manubriosternal fusion, Szeged-Kiskundorozsma M5 Kettőshatár, gr. no. 513.

Figure 3: Sternoxiphoidal fusion, Győrszentiván-Révhegyi tag, S-0463, young adult male.
Figure 4: Total fusion of the sternum, Győrszentiván-Révhegyi tag, S-0442, elderly female.
Figure 5/a: Caudal clefting of the sternum.
Figure 5/b: Caudal clefting of the sternum, Szeged-Kiskundorozsma M5 Kettőshatár, gr. no. 521.
Figure 6: Mesosternum shape variation.
Figure 7: Pectus carinatum, Győrszentiván-Révhegyi tag, S–442, elderly female.

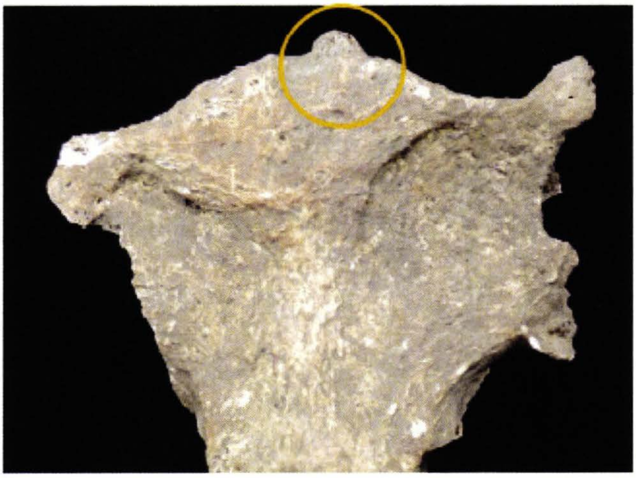

Figure 1.

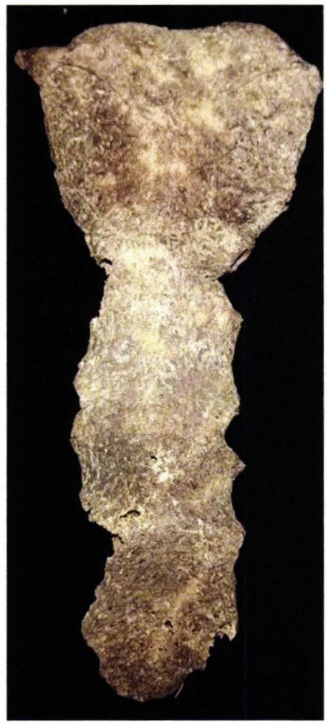

Figure 2.

Figure 3

Figure 4.

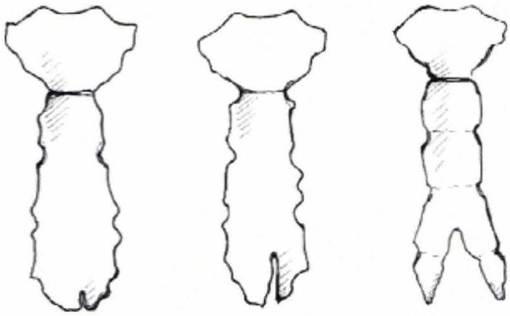

Figure 5/a

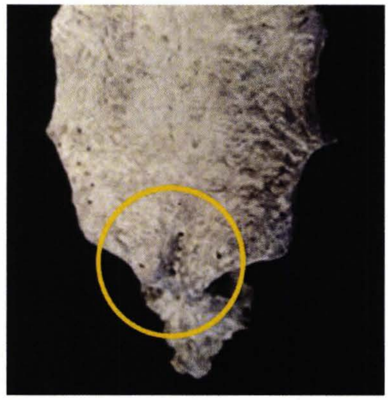

Figure 5/b.

Figure 6.

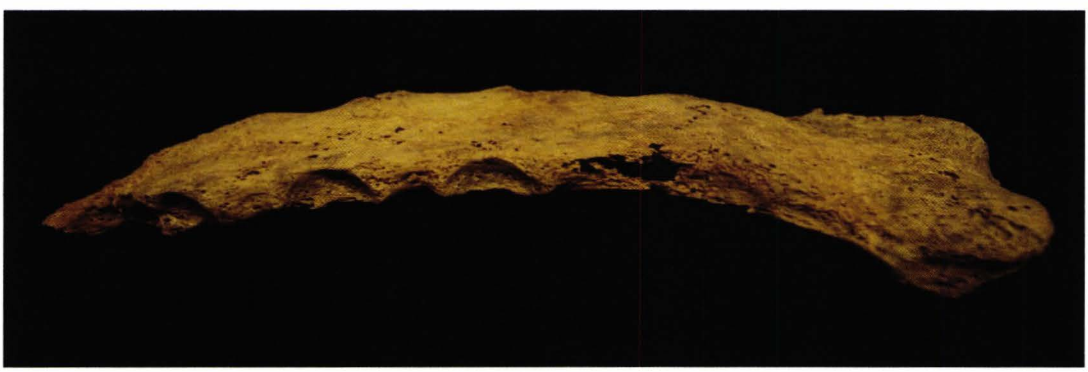

Figure 7.

PALEOPATHOLOGICAL STUDY AND GRAPHICAL RECONSTRUCTION OF A 7–8TH CENTURY SPINAL TB CASE

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Keywords: Hungary, Avar Age, tuberculous spondylitis, Pott's paraplegia, graphical reconstruction, visual paleopathology

Abstract

This paper presents a multiple site case of tuberculous spondylitis and other possibly associated conditions in an Avar Age (7th–8th century) female from Hungary. Tuberculous process of the thoracic vertebrae 3–6 resulted in a classic angular kyphosis. The alterations in the basis of the sacrum and the changes of the hip joints suggest also a tuberculous process. The collapsed and fused vertebral bodies were evaluated by morphological and radiological (conventional X-ray and 3D CT examination) methods. The atrophy and abnormal gracility of the limb bones reveal that our patient had been unable to walk during great many years preceding her death. This paralytic condition was most probably the consequence of a Pott's paraplegia (Marcsik et al., 1999). Paleomicrobiological results have also proved the presence of M. tuberculosis complex DNA in these skeletal remains (Haas et al., 2000).

Based on the morphological, paleomicrobial and paleoradiological results, it was relatively easy to establish the diagnosis of spinal TB associated with probable paraplegia. Specialists of this field understand the lesions and can interpret them, but have no real vision about the individual and its suffer. Moreover, non-expert public cannot imagine what is behind the skeletal changes, and what this ill person looked like. Recognizing this, we propose a new approach and to develop visual paleopathology as new research field. With the help of this, we visualized a probable appearance of this Avar Age young woman who suffered from a severe complex of diseases.

Introduction

The skeletal remains of an Avar Age (7th–8th century, Gr. no. 19, Sükösd-Ságod cemetery, Hungary) female, who died in her early 20's, show serious pathological lesions. The skeleton, stored in the collection of the Department of Biological Anthropology, University of Szeged, were first studied by Antónia Marcsik in the 1970's. Preliminary macromorphological studies established the diagnosis of a generalised skeletal tuberculosis[1]. According to the paleopathological and

[1] Marcsik, 1972.

medical literature[2], our case is a typical and classic example of tuberculous spondylitis, and one of the most evident ancient skeletal TB cases from Hungary[3]. The morphological diagnosis was confirmed by molecular biological methods, too[4].

Results and Discussion

Tuberculous spondylitis involving thoracic vertebrae 3–6 with classic angular kyphosis and subsequent pressure resorption on thoracic vertebrae 1 and 2 above, and 7 and 8 below can be observed (Figure 1). Traces of paravertebral abscess, probably active at the time of the original pathology, are found on thoracic vertebrae 8–10. The macroscopic analysis revealed bilateral occlusion of the T3-T4 intervertebral foramen.

The conventional lateral view X-ray examination shows anterior fusion of C7 and T1. T1 is wedge-shaped. The bodies of T2-T7 are fused, forming block vertebra. At this level 90% of kyphosis is present. Because of the adjacent ribs, the width of the spinal canal cannot be evaluated. The disc spaces are narrowed between C6-C7, C7-T1, T1-T2, and to a lesser extent between T7-T8 and T8-T9. T9 is also slightly wedge-shaped. Some beginning degenerative changes can be seen on the lower segments.

The 3D multiplanar CT examination, sagittal view /Siemens Somatom Plus 4/ reveals that the spinal canal is preserved even at this level of kyphosis. The form of the collapsed and fused vertebral bodies can be further evaluated, as well as the extreme narrowing/occlusion of some intervertebral foramen (Figure 2). The 3D surface-shaped technique (3D-SSD)/Siemens Somatrom Plus 4/ (Figure 3) shows the inner surface of the spinal canal, with its almost normal width and the occlusion of the intervertebral foramen T3-T5.

The changes of the hip joints suggest a primary infectious process and secondary degenerative alterations. On the left side we can observe severe hip dislocation and accommodation by developing secondary joints between the lesser trochanter of the femur and on the pubic bone, anterior to the acetabulum (Figure 4).

There are significant additional alterations in the lower skeleton, which may be due to the active phase of TB, but may also be due to other associated infectious lesions, disuse atrophy or outright paralysis. Due to the multiple locations and extensive remodelling of the axial and pelvic skeleton, it is very hard to separate the possible states of the disease, consequently the specific timing of these disease phases is difficult to ascertain.

Based on the presence of the severe angular kyphosis, the suggested angle between the femora and the pelvis, and the angle between the sacrum and lumbar spine, we believe that the living individual was immobile, „sitting" in a severe hunchback position (Figure 5).

Subsequent skeletal changes suggest that TB was contracted at a relatively early age – possibly around 8 or 10 – this being the active phase, and then the woman underwent another 10 to 12 years of remodelling and bone accommodation.

As the limb bones present remarkable atrophy and abnormal gracility, we assume that our patient had been unable to walk during great many years preceding her death. The occlusion of the intervertebral foramina T3-T5 could certainly provoke some nervous complications, however, the above mentioned paralytic condition was most probably the consequence of a Pott's paraplegia[5].

Although, the CT-examinations reveal the preserved spinal canal in the examined dry bones, during the years of the active disease, the compression of the spinal cord by a significant amount

[2] Ortner and Putschar, 1985; Resnick and Niwayama, 1988.
[3] Marcsik and Pálfi, 1992, 1993; Marcsik *et al*, 1999; Pálfi, 2002.
[4] Haas *et al.*, 2000.
[5] Martini and Ouahes, 1984, Moon *et al*, 2003.

of the extradural mass of tubercoulous debris, could provoke this serious complication[6]. In conclusion, we can assume that the tuberculous lesions of the spine healed by fusion (with severe kyphosis), but recovery from paraplegia was probably not obtained, and the patient remained paralyzed for the second half of her (short) life.

Based on the above menitioned morphological, paleomicrobial and paleoradiological results, it was relatively easy to establish the diagnosis of spinal TB associated with probable paraplegia. Specialists of human osteoarchaeology and paleopathology understand these lesions and can interpret them, but have no real vision about the individual and its suffer. Moreover, non-expert public cannot imagine what is behind the skeletal changes, and what this ill person looked like. Recognizing this, we are proposing a new approach and to develop visual paleopathology as new research field.

Artistic anatomy, graphical and plastical face reconstruction have a long tradition in Hungary[7]. However, 'visual anthropology' (graphical and plastical face reconstruction) is essentially (or quasi-exclusively) works on the visualisation on normal anatomical structures. We have no (or not enough) reconstructed paleopathological bodies or paleopathological face reconstructions with pathological lesions. The first attempt for the visualisation of paleopathological cases was the plastical face reconstruction of two cases (head trauma and *facies leprosa*) by Ágnes Kustár, for an exposition of the Ópusztaszer Historical Heritage Park[8]. Visual paleopathology appeared at the first time in the graphical works of Luca Kis, at the exhibition 'Talking Dead' in the Móra Ferenc Museum, Szeged[9].

In case of the presented Avar Age Pott's disease, the reconstruction process started with the rebuilding of the skeleton according to Antónia Marcsik[10] (Fig. 5). In addition, we used a large amount of ancient clinical data[11] (Fig. 6) and modern clinical cases of well developed Pott's disease deformations (Fig. 7a,b), pictures in order to represent the proper ratios of the body deformation related to the skeletal lesions.

Experimental archaeological method – a living model – was also used to check the anatomical position and compensate the missing bones and soft tissues (Fig. 8a,b). The experimental archaeological tests revealed that in the previously reconstructed anatomical position the left leg basically could not reach the ground, only if it was hanged up (Fig. 7a). We decided to change the main position and moved the trunk in the line of the sagittal plain (Fig. 7b). In this position the head could not be elevated despite of the maximum extension of the cervical vertebrae. The precise reconstruction of the face does not belong to the aim of this investigation; therefore, it was created in a turned away position with general and simple hair style. The outfit contains simple textile clothes which match the socio-archaeological aspects of the cemetery[12]. The known archaeological material of the Sükösd-Ságod cemetery does not contain any equipment that can help in the reconstruction[13]. The lack of the primary sources forced us to use more general written data[14] and analogies from other Avar Age cemeteries: textile remains[15] and other inorganic elements of the outfit[16]. The leather

[6] Martini, 1988; Cremin and Jamieson, 1995.
[7] Barcsay, 1953; Kőnig, 2013, 2017; Kustár, 1998, 1999, 2004; Kustár and Árpás, 2008; Kustár and Skultéty, 1996; Kustár *et al*, 2011.
[8] Pálfi *et al*, 2010.
[9] Szilágyi and Bereczki, 2018.
[10] Marcsik *et al.* 1999.
[11] Sorrel and Sorrel-Déjeurine, 1932.
[12] Adam 2003.
[13] Adam 2003.
[14] Szádecky 1992.
[15] T Knotik 2003.
[16] Kürti and Lőrinczy 1991, László 1955.

shoes, the pants, and the long-sleeved top are known elements of the female wear in the Avar Age[17], furthermore, they do not hide the physical condition of the individual.

Figure 9 presents the result of our attempt of visual paleopathology: the graphical reconstruction of the young female specimen, based on the anthropological material from the grave No. 19 of the Avar Age cemetery of Sükösd-Ságod.

It is clear that a visual reconstruction cannot precisely represent the past life as it is a multivarious process with a lot of missing data, but visual paleopathology can give a unique opportunity for scientists and non-expert people to imagine the person and the effects of the illness behind the examined skeleton. In addition, it helps to make the results of this research field more comprehensive, and also to popularize this field of science itself.

Acknowledgement

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Legend of figures

Figure 1: Thoracic vertebrae with angular kyphosis of tuberculous origin (7th–8th century, Gr. No. 19, Sükösd-Ságod cemetery, Hungary. Young adult female).

Figure 2: Sagittal view 3D multiplanar CT examination revealing the preserved spinal canal and the extreme kyphosis.

Figure 3: Sagittal view 3D surface-shaped technique (3D-SSD) showing the inner surface of the spinal canal, with its almost normal width and the occlusion of the intervertebral foramen.

Figure 4: Pathological changes of the left hip joint (primary infectious process and secondary degenerative alterations), and accommodation by developing secondary joints.

Figure 5: Reconstruction of the skeleton of the young female specimen.

Figure 6: Clinical case study of an old Pott's disease (from: Sorrel and Sorrel-Déjeurine, 1932).

Figures 7a, b: Modern cases with advanced stage chronic Pott's disease (form: www.africasurgery.org).

Figures 8a, b: Re-examination of the possible anatomical positions and movements on a living-model. The tests revealed that in the former reconstructed position the left leg could not reach the ground (a), and a more bended position was needed (b).

Figure 9: Graphical reconstruction of the young female specimen, based on the anthropological material from the grave No. 19 of the Avar Age cemetery of Sükösd-Ságod.

Figure 1

Figure 2

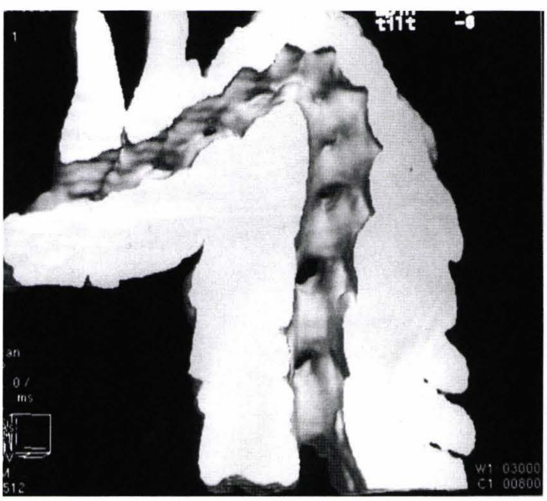

Figure 3

Figure 4

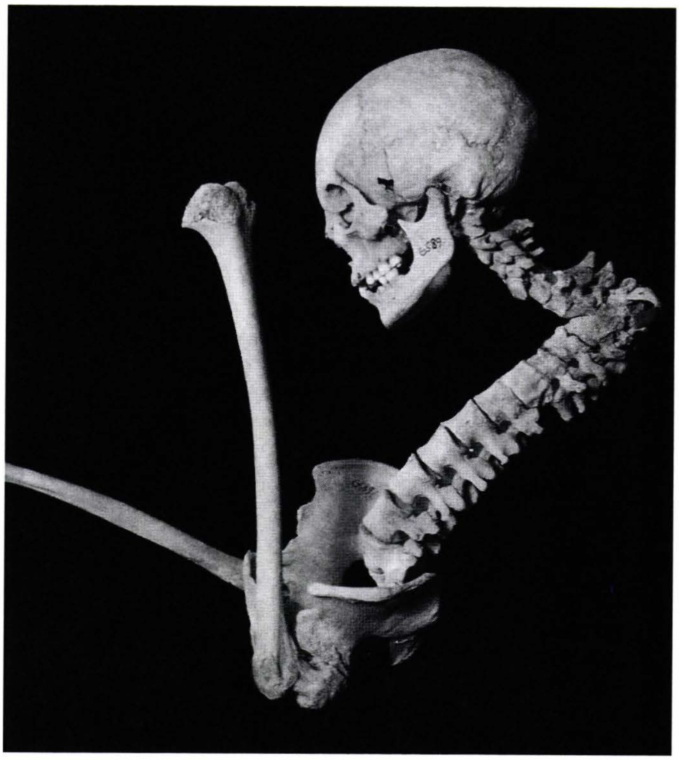

Figure 5

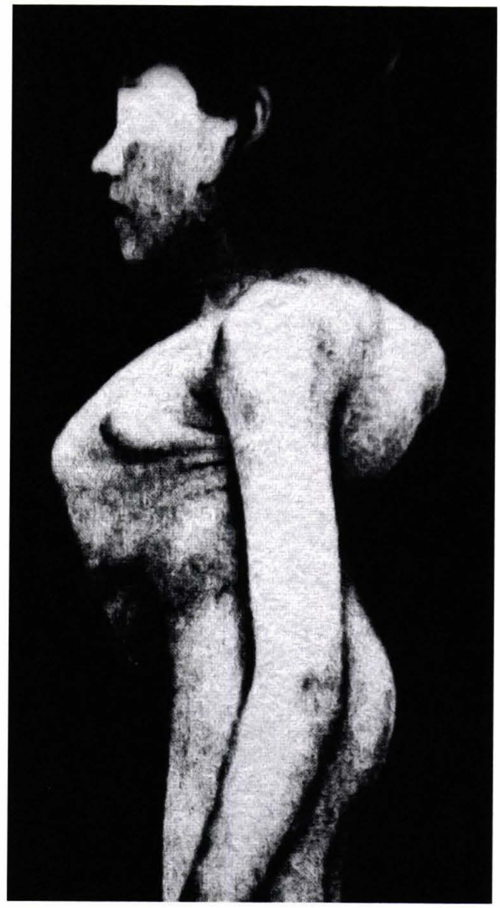

Figure 6

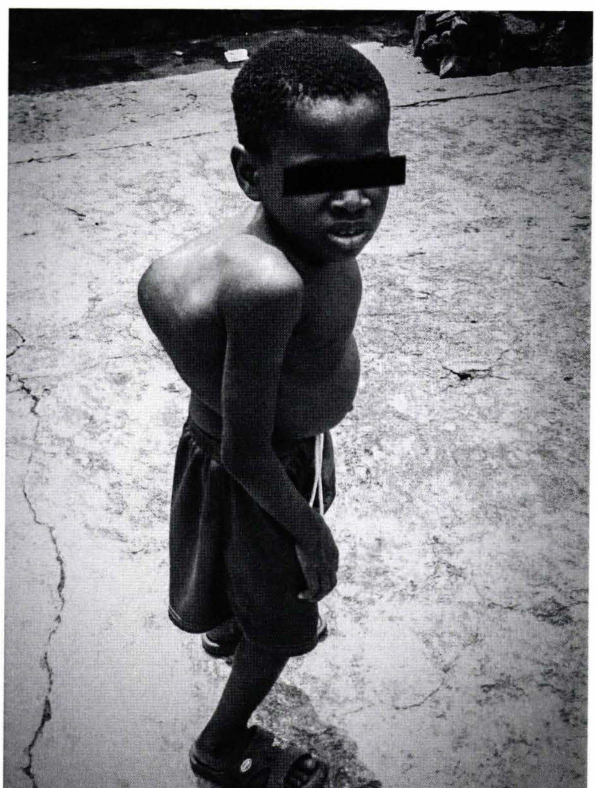

Figure 7a

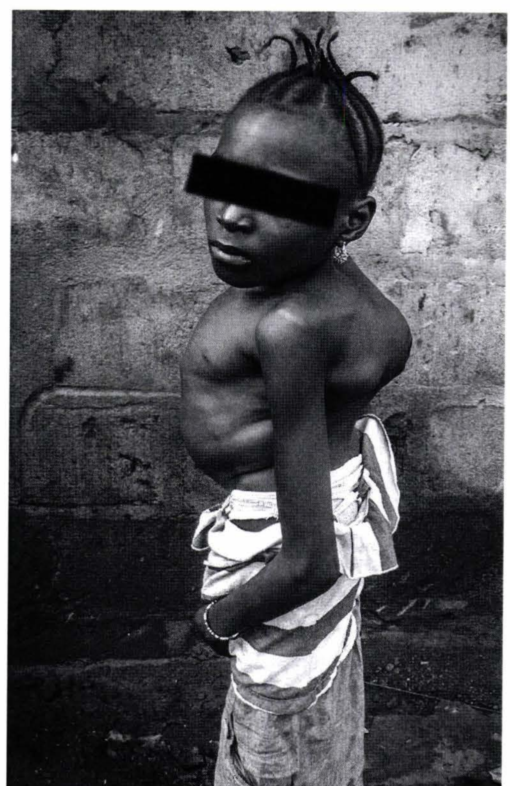

Figure 7b

Figure 8a

Figure 8b

Figure 9

MITOGENOMIC DATA IMPLY A SIGNIFICANT ASIAN HUN COMPONENT IN THE HUNGARIAN CONQUERORS WICH WAS ADMIXED WITH EUROPEANS OF SRUBNAYA ORIGINS

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Keywords: mitogenomic data, Asian Hun component, Hungarian Conquerors, Srubnaya origins

In the last few years our young research group has been studying the genetic composition of the Hungarian Conquerors, who arrived in the Carpathian Basin in 895 and established the Hungarian State. Here we present our first results about the genetic structure and relationships of the Hungarian conquerors, and also report our preliminary results about the genetic structure of modern Hungarians, and their relation to the Conquerors.

According to the prevailing academic theory the Hungarian language was brought in the Carpathian Basin by the conquering Hungarians, which supposedly originated from proto Finno-Ugric people east of the Ural. Now we have the possibility to test this hypothesis genetically, as archaeogenetic research is well suited to determine the origin of populations based on their genetic composition. The genetic composition of the Conquerors were studied previously with traditional PCR based methods.[1] In these studies only the most polymorphic HVR region of the maternally inherited mitochondrial DNA was amplified and sequenced, but this gives very unreliable short sequence reads, limiting the resolution of the genetic analysis. In the last years the ancient DNA field underwent a revolutionary technical development, with the introduction of Next Generation Sequencing method, which can provide very reliable sequence reads from the entire mtDNA genome.

We studied mainly three early Conqueror cemeteries located at the Bodrogköz region near Karos village, which are considered to represent the military elite, their families and servants[2].

[1] Csősz et al. 2016; Neparáczki et al. 2016; Tömöry et al. 2007.

[2] Révész 1996.

Altogether we have sequenced 102 mitogenomes; representing nearly the entire population from the three Karos cemeteries and a few samples from other Conqueror cemeteries. As each individual may have independent origin, we handled each individual independently, and traced their maternal origin one by one. The phylogenetic relations of maternal lineages clearly indicate their geographic origin. The 102 samples belonged to 67 subhaplogroups, thus we assembled 67 phylogenetic lineages.In order to achieve the highest possible resolution we compared these sequences to all known mtDNA sequences from all over the world, including 32683 modern and 420 ancient Eurasian mitogenomes. We aligned these sequences into phylogenetic trees and looked up the geographic origin of the closest matching samples Figure 1.

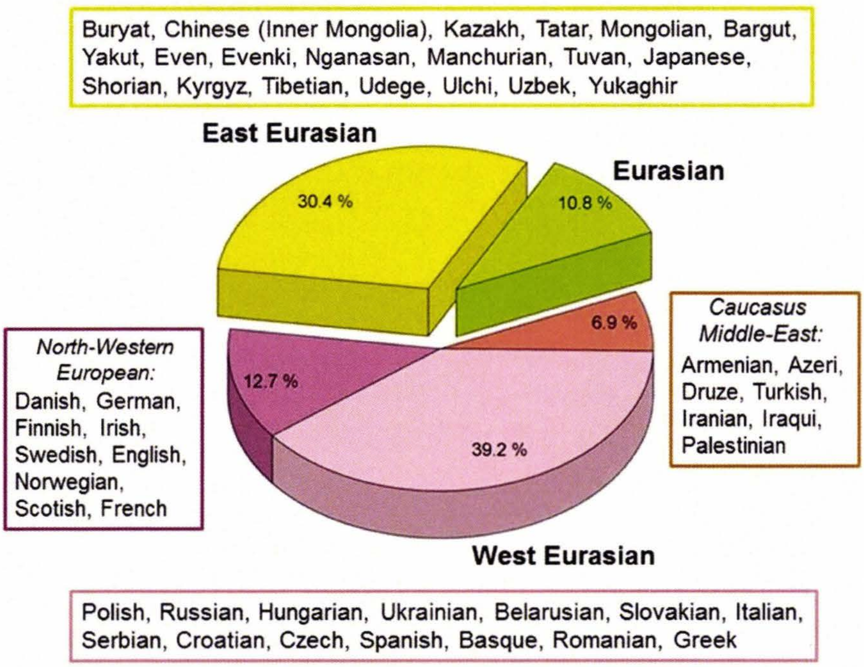

Figure 1. Phylogeographic origin of the 102 Conqueror maternal lineages. Origin of modern individuals with closest matches to Conqueror sequences are listed next to the indicated regions, ordered according to the frequency of appearances.

This so called phylogeographic approach indicated that 31% of the Conquerors were clearly derived from East-Inner Asia, as their closest sequence matches were found among modern Buryat, Bargut, Chinese, Mongolian, Tatar, Yakut, Even, Evenk, Udege, Ulchi, Tuvan, Tibetian, Japan, Nganasan, Yukaghir, Uzbek, Kazakh people. About 10% of the lineages have a wide Eurasian distribution, but the closest matching samples suggested that most of these also came from Asia, and probably originated from Asian Scythians. The majority of lineages were of European origin, a smaller subset of these originated in the Caucasus region or the Middle East, another 12% has its closest genetic relatives in North-Western Europe. None of the Conquerors had north-western Siberian origin, thus our data do not support the prevailing theory. This conclusion is most obvious from the distribution of Asian sequence matches. If we project on the map all of the 31 independent Asian matches they all fall within the territory of the Asian Hun(Xiongnu) Empire, and most of them fall around Northern Mongolia, were the center of the Xiongnu empire was located. These data raise the possibility that the Conquerors may have Asian hun origin.

We have also performed population genetic analysis, testing the similarity of populations instead of individuals. As it was obvious that the Conquerors were assembled from at least two different populations originating from Asia and Europe, we assembled five hypothetical subgroups from our Conqueror population, and compared each to all available modern and ancient populations Figure 2.

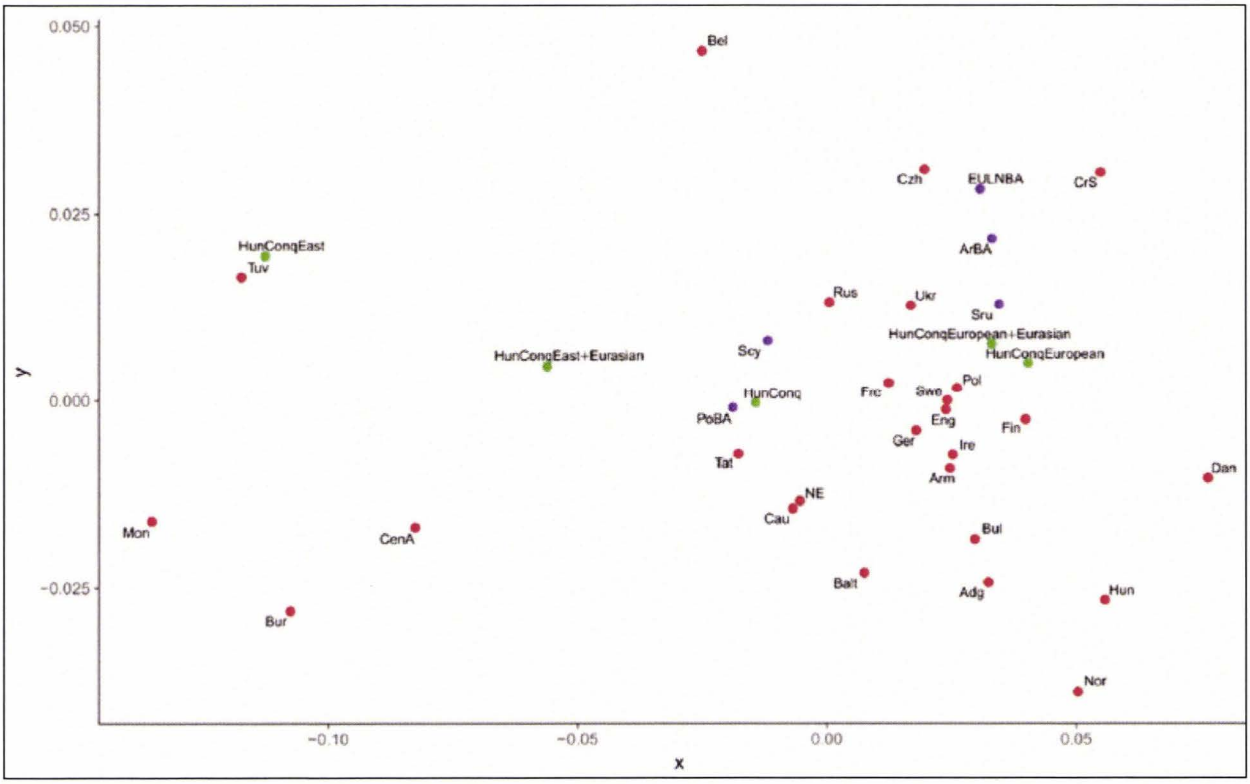

Figure 2. MDS plot from linearized Slatkin Fst values.
Conqueror subgroups, corresponding to Figure 1, are labeled green, modern populations are labeled red, ancient populations are labeled with blue dots.

Not surprisingly the Asian subset identified the same groups, Tuvinians, Mongolians, Buryats and Central Asians. The European subset falls into the vicinity of European populations, but the closest matching fit is the ancient Srubnaya population. If all Conquerors were grouped together their closest matching populations were Volga Tatars, European Scythians, and the Poltavka-Potpovka ancient cultures. Thus the European Conqueror component was most probably derived from the Late Bronze Age Srubnaya people, who lived a semi-nomadic way of life north of the Black See. Genetic results have shown that their ancestors were the Early Bronze Age Yamnayas, and their Iron age descendants were the Scythians and Sarmatians. Taken together the European component also originated from the steppe not from northern forest zone, the home of Finno-Ugrics.

The most interesting question is to identify Medieval historical populations which are closest to the Conquerors. The genetic implication for this comes from the Volga Tatar relations, as our analysis indicated that the Conquerors correspond to a major genetic component of Tatars, but the opposite is not true (data not shown). Volga Tatars were assembled from three main ethnic components; Volga Bulgars, which arrived in the 8^{th} century, and intermingled with local Scythian and Finno-Ugric populations, then in the 13^{th} century Kipchak Tatars of the Golden Horde brought a final Central-Inner Asian genetic layer and their language to the region[3]. It is very feasible to suppose that the Conqueror component of the Tatars correspond to Onogur Bulgars, as this is also supported by archaeological, anthropological and linguistic data. Both groups had similar

[3] Malyarchuk et al. 2010.

grave goods, including partial horse burial[4], had similar anthropological types[5] and practiced similar symbolic trephination customs[6]. The name "Hungarian" is supposedly have derived from "Onogur"(Róna-Tas 1999).

Based on our data the most feasible scenario about the origin and composition of the Conuerors is the following: Most of their east Eurasian lineages were ultimately originated from East-Inner Asia, South Siberia centering around modern Mongolia and Buryatia, which overlaps the territory of the ancient Xiongnu empire. When Asian Huns moved to Central Asia they intermingled with descendants of Asian Scythians, who contributed Eurasian lineages. Then as Huns moved further to Europe they assimilated with other nomads of the Pontic steppe which carried European genetic lineages Figure 3.

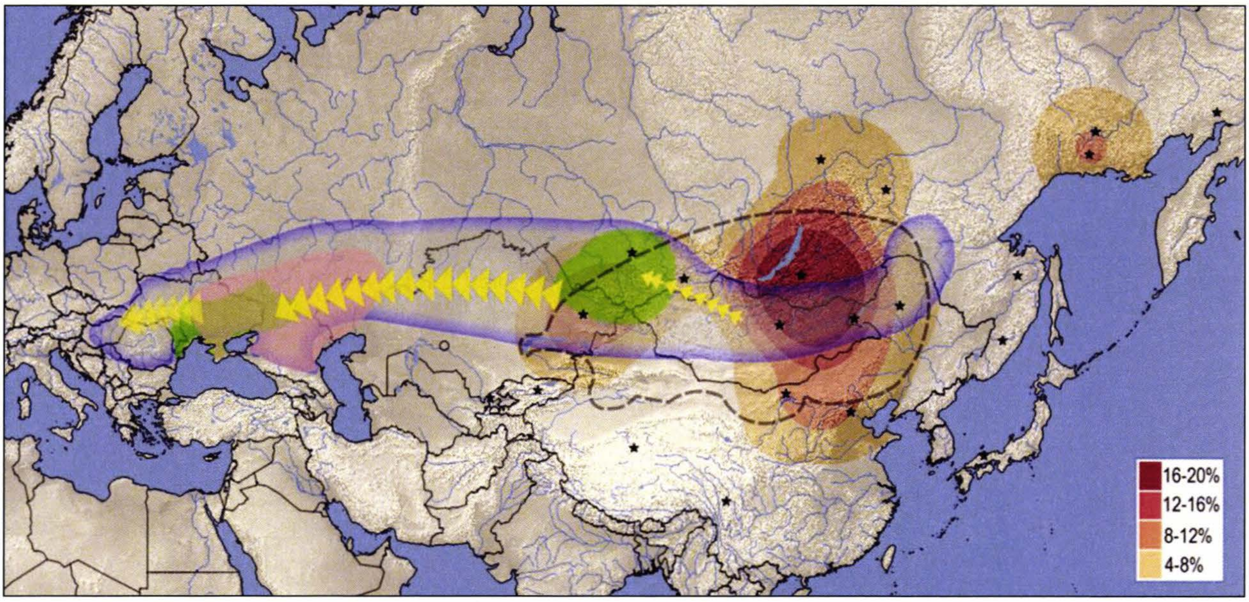

Figure 3. The most feasible origin and migration route of different components of the Hungarian Conquerors based on our study.

Red heat map displays the geographic distribution of closest East Eurasian sequence matches to individual Conqueror samples, thus heat map designate the area from which the East Eurasian lineages most likely originated, well corresponding to the range of the ancient Xiongnu Empire outlined by dashed line. Areas where Asian and European Scythian remains were found are labeled green. Asian Scythians around Tuva correspond to the most probable sources of Eurasian lineages. Pink label shows the presumptive range of the Srubnaya culture, from where European lineages were most likely derived. Bluish line frames the Eurasian steppe zone, within which all presumptive ancestors of the Conquerors were found.

We can raise the question as to what extent can our findings be generalized to the entire Conqueror population. Our fragmentary data from other cemeteries indicate the presence of the same Eastern and Western genetic components, moreover[7] reported 101 other Conqueror HVR haplotypes from 24 cemeteries, which show very similar major Hg distribution to our samples, with even larger proportion of Asian major Hg components. Thus our conclusions probably apply to the entire Conqueror population, but definitely to the 10th century immigrant military elite characterized with partial horse burials.

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4 Türk 2014.

5 Fóthi 2006.

6 Bereczki et al. 2015.

7 Csősz et al. 2016, Tömöry et al. 2007.

Finally our data are completely in line with genomic data from modern populations. In a recent paper Hellenthal et al studied the genetic components of several modern populations including Hungarians[8] with Admixture analysis and detected 4% East-Inner Asian component in modern Hungarians, and all of the other components which we detected in the Conquerors (Caucasian and Northern-Western European) were present in modern Hungarians. The time of this admixture was dated between 400–1000 AD, perfectly coinciding with the invasion of Huns, Avars and Hungarians.

We also tested the genetic relations of modern Hungarians, and our results are very surprising. The studied Conquerors contributed just approximately 3–5% to modern Hungarians in agreement with genomic data[9]. Moreover according to our data modern Hungarians have ancient European origin, as they mostly carry ancient lineages derived from Neolith-Bronze Age, which are most similar to Danish, Dutch-Belgian, Basque and Italian populations. We found that modern Hungarians are admixed with neighboring groups less than 15%.

As the most feasible ancestors of the Conquerors – Onogurs – spoke Turcic language and genetic data indicate that the Conquerors did not contribute significantly to Hungarian ethnogenesis, moreover anthropological data indicate that the subsequent Árpádian Age population is more similar to preconquest Avar age people than to the Conquerors[10], we may risk an alternative hypothesis, namely that the Hungarian language might not be connected to the Conquerors but rather to preconquest populations of the Carpathian Basin.

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ENDOCRANIAL BONY CHANGES PROBABLY RELATED TO TUBERCULOUS MENINGITIS – EXAMPLE CASES FROM THE ROBERT J. TERRY ANATOMICAL SKELETAL COLLECTION (WASHINGTON, DC, USA)

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Abstract

Tuberculosis (TB) is one of the oldest known infectious diseases that has been plaguing humans for thousands of years. Traditionally, the palaeopathological diagnosis of TB relies on the identification of lesions in the skeleton that can be related to different forms of the disease (e.g., pulmonary TB, osteoarticular TB, and TB meningitis). Since the late 20th century, a number of endocranial alterations (i.e., abnormally pronounced digital impressions,periosteal appositions, abnormal blood vessel impressions, and granular impressions) have been attributed to TB meningitis in the palaeopathologial literature. However, the diagnostic value of these lesions has more recently been questioned,as their precise aetiology is still a matter of controversy. Additionally, similar or even the same morphological features can also be found in non-TB-related cases, such as in non-specific inflammatory (e.g., bacterial meningitis) and haemorrhagic (e.g., epidural haematoma)processes. To strengthen the diagnostic value of the above-mentioned endocranial alterations in the palaeopathological diagnosis of TB, a detailed macroscopic investigation, focusing on the macromorphological characteristics, frequencies, and co-occurrences of these bony changes, was performed on human skeletons of known age at death, sex, and cause of death from the Robert J. Terry Anatomical Skeletal Collection (National Museum of Natural History, Smithsonian Institution, Washington, DC, USA). The aim of our study is to discuss in detailthree example cases from the Terry Collection that show endocranial alterations indicative of TB meningitis, and to interpret the observed lesions with regard to their diagnostic value in the palaeopathological practice. Our paper provides palaeopathologists with a stronger basis for identifying TB in ancient human remains that reveal endocranial alterations resembling that of our cases; and therefore, with a more sensitive means of assessing TB prevalence in past populations.

Introduction

Tuberculosis (TB) is one of the oldest known infectious diseases that has been plaguing humans for thousands of years[1]. It is caused by a number of pathogenic mycobacterial species that belong to the *Mycobacterium tuberculosis* complex, with *M. tuberculosis* being the most common

[1] Gagneux, 2012; Galagan, 2014.

cause of TB in humans[2]. TB bacteria are usually transmitted by the airborne route; therefore, the disease primarily affects the lungs (*i.e.*, pulmonary TB)[3]. Nonetheless, the haematogenous or lymphogenous spread of the pathogens to other parts of the body, including the skeleton or the central nervous system, results in the development of extra-pulmonary forms of tuberculosis(*e.g.*, miliary TB, osteoarticular TB, and TB meningitis (TBM))[4].

Traditionally, the diagnosis of TB in ancient human bone remains relies on the identification of pathological lesions in the skeleton that are related to different types of TB, such as pulmonary TB, osteoarticular TB, and TBM[5]. Since the late 20th century, palaeopathological studies on osteoarchaeological series[6] and documented skeletal collections[7] have revealed a positive correlation between TB meningitis and a number of endocranial bony changes, namely abnormally pronounced digital impressions (APDIs), periosteal appositions (PAs), abnormal blood vessel impressions (ABVIs), and granular impressions (GIs).However, the diagnostic value of the aforementioned alterations has more recently been questioned[8], as their precise aetiology is still a matter of controversy, and additionally, similar or even the same morphological features can be found in non-TB-related cases, such as in non-specific inflammatory (*e.g.*, bacterial meningitis) and haemorrhagic (*e.g.*, epidural haematoma) processes.

In the last three decades, the Terry Collection has been used to define and refine paleopathological diagnostic criteria for tuberculosis in several studies[9]; however, the probable TBM-associated endocranial lesions (*i.e.*, APDIs, PAs, ABVIs, and GIs) were beyond the scope of the above-mentioned research projects. To strengthen the diagnostic value of these endocranial alterations in the palaeopathological diagnosis of TB, a detailed macroscopic investigation, focusing on their macromorphological characteristics, frequencies and co-occurrences, was performed on human skeletons of known age at death, sex, and cause of death from the Robert J. Terry Anatomical Skeletal Collection (National Museum of Natural History, Smithsonian Institution, Washington, DC, USA). The aim of our study is to discuss in detail three example cases from the Terry Collection that show endocranial alterations indicative of TBM, and to interpret the observed lesions with regard to their diagnostic value in the paleopathological practice.

Materials & Methods

The Robert J. Terry Anatomical Skeletal Collection – currently curated in the Department of Anthropology at the National Museum of Natural History (NMNH) (Smithsonian Institution, Washington, DC, USA) – consists of 1,728 human skeletons[10]. For each individual, a series of documentary forms providing various biographical information (*e.g.*, age at death, sex, and cause of death) and basic anthropological data is available at the NMNH[11]. Therefore, the Terry Collection serves as an invaluable resource for anthropological and medical research, including developing

[2] Gagneux, 2012; Pai *et al.*, 2016.
[3] Flynn & Chan, 2001; Flynn *et al.*, 2011; Pai *et al.*, 2016.
[4] Flynn & Chan, 2001; Golden & Vikram, 2005; Pai *et al.*, 2016.
[5] Kelley & Micozzi, 1984; Aufderheide & Rodríguez-Martín, 1998; Ortner, 2003, 2008; Santos & Roberts, 2006; Pálfi *et al.*, 2012; Mariotti *et al.*, 2015.
[6] Schultz, 1993, 1999, 2001, 2003; Templin & Schultz, 1994; Teschler-Nicola *et al.*, 1994, 2015; Jankauskas & Schultz, 1995; Jankauskas, 1999; Maczel, 2003; Schultz & Schmidt-Schultz, 2015.
[7] Hershkovitz *et al.*, 2002; Maczel, 2003; Schultz & Schmidt-Schultz, 2015.
[8] Lewis, 2004; Roberts *et al.*, 2009; Janovic *et al.*, 2015.
[9] Roberts *et al.*, 1994; Winland *et al.*, 1997; Rothschild & Rothschild, 1998, 1999; Pálfi *et al.*, 2012.
[10] Hunt & Albanese, 2005.
[11] Hunt & Albanese, 2005.

new criteria for the diagnosis of specific infectious diseases in osteoarchaeological series from the pre-antibiotic era[12].

As part of a comprehensive research project, a detailed investigation was performed on all specimens (N=302) with TB as the cause of death from the Terry Collection, and on a control group consisting of randomly selected individuals (N=302) from the remaining specimens of the Collection with non-TB causes of death[13]. The macroscopic evaluation of the 604 selected skeletons focused on the macromorphological characteristics, frequencies, and co-occurrences of pathological alterations probably related to different forms of TB[14]. These are the following:

- Bony changes indicative of osteoarticular TB (osteolytic or erosive vertebral lesions, collapse or fusion of the vertebral bodies, vertebral hypervascularisation, cortical remodelling and reactive new bone formation on the vertebral surfaces, signs of osteomyelitis of the extra-spinal bones, and destruction, subluxation or dislocation of the intervertebral or extra-spinal joints)[15];
- Lesions suggestive of pulmonary TB and/or TB pleurisy (periosteal new bone formations (PNBFs) on the visceral surface of ribs, erosive costal changes, and signs of diffuse, symmetrical periostitis on the diaphysis of short and long tubular bones)[16]; and
- Endocranial alterations likely associated with TBM (APDIs, PAs, ABVIs, and GIs)[17].

All bones of the selected specimens were macromophologically evaluated. For each surveyed individual, detailed written and pictorial descriptions of all observed probable TB-related alterations were made on a data collection sheet[18]. Among the 604 evaluated skeletons from the Terry Collection, there were only six specimens recorded to have died of TB meningitis; nonetheless, bony changes probably associated with TBM were identified in a number of cases[19]. In our paper, the following three skeletons from the Terry Collection were selected for discussion in detail:

- **Terry No. 522**: a 30-year-old (1897–1927) male recorded to have died of pulmonary TB. The skeleton is well-preserved and complete;
- **Terry No. 1222**: a 28-year-old (1905–1934) female whose morgue record states pulmonary TB as the cause of death. The skeleton is well-preserved and complete; and
- **Terry No. 1322**: a 34-year-old (1900–1934) male registered to have died of pulmonary TB. The skeleton is well-preserved and complete.

Results & Discussion

In the skeleton of **Terry No. 522** – a 30-year-old male recorded to have died of pulmonary TB –, pathological bony changes that may be ascribed to tuberculosis were registered in both the cranial and postcranial elements. As for the skull, multifocal GIs – described by *Schultz*[20] as pathognomonic signs of TBM, since representing pressure atrophy of the tubercles – were detected on the squamous part of the frontal bone **(Fig. 1A)**, in the right parietal bone along the squamous suture

[12] Hunt & Albanese, 2005.
[13] Spekker, 2018.
[14] Spekker, 2018.
[15] Aufderheide & Rodríguez-Martín, 1998; Baker, 1999; Maczel, 2003; Ortner, 2003, 2008; Giacon, 2008; Mariotti *et al.*, 2015.
[16] Mensforth *et al.*, 1978; Kelley & Micozzi, 1984; Roberts *et al.*, 1994; Winland *et al.*, 1997; Rothschild & Rothschild, 1998, 1999; Santos & Roberts, 2001, 2006; Hershkovitz *et al.*, 2002; Maczel, 2003; Matos & Santos, 2006; Giacon, 2008; Mariotti *et al.*, 2015.
[17] Mensforth *et al.*, 1978; Schultz, 1993, 1999, 2001, 2003; Hershkovitz *et al.*, 2002; Maczel, 2003; Lewis, 2004; Schultz & Schmidt-Schultz, 2015.
[18] Spekker, 2018.
[19] Spekker, 2018.
[20] Schultz 1999, 2001, 2003) and Schultz&Schmidt-Schultz 2015.

(Fig. 1B), and on the squamous part of the left and right **(Fig. 1B)** temporal bones and of the occipital bone. Furthermore, non-specific vestiges of haemorrhagic and/or inflammatory meningeal reactions –namely multifocal, small, serpentine branching ABVIs accompanied by slight PAs[21] – were observed in the left parietal and occipital bones, covering less than one-fourth of the inner surfaces. Moreover, shallow APDIs were noted on the squamous part of the frontal bone, probably referring to elevated intracranial pressure (eICP) secondary to TBM[22].

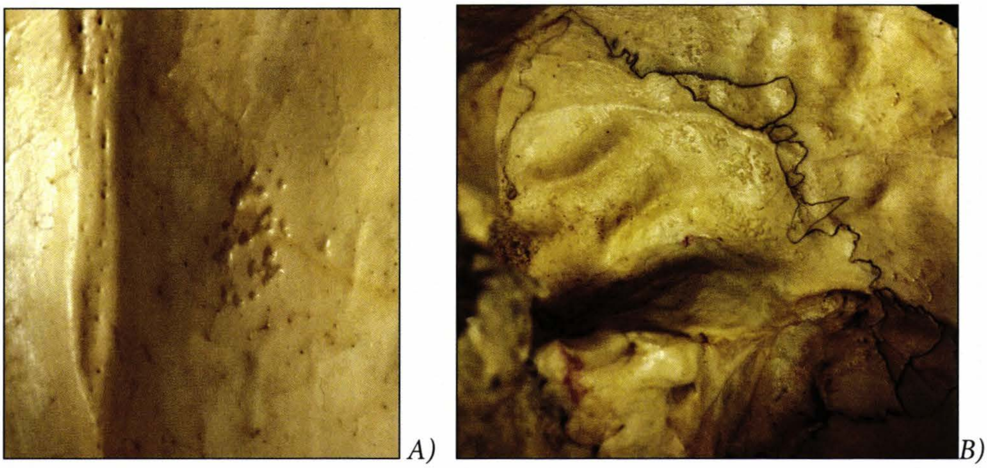

Figure 1: GIs A) on the squamous part of the frontal bone and B) along the squamous suture in the right parietal and temporal bones (Terry No. 522, 30-year-old, male, pulmonary TB).

Besides the endocranial alterations very likely associated with TBM, very slight PNBFs – frequently described as not specific but probable signs of pulmonary TB and/or TB pleurisy[23] – were noted on the visceral surface of the vertebral end of four left side (4th–7th) and ten right side (2nd–11th) ribs. The recorded cause of death of Terry No. 522 supports the tuberculous origin of the detected endocranial and costal changes.

The cranial elements of **Terry No. 1222** – a 28-year-old female registered to have died of pulmonary TB –,showed different types of endocranial alterations that may be attributed to tuberculosis. GIs, described by *Schultz*[24] as pathognomonic features of TBM, were detected on the left greater wing of the sphenoid bone and on the squamous part of the occipital bone **(Fig. 2)**, covering less than one-fourth of the inner surfaces.

Moreover, multifocal, small, serpentine branching ABVIs accompanied by slight PAs, referring to non-specific vestiges of inflammatory-haemorrhagic meningeal processes[25], were noted along the sagittal sinus and around the most protruding portions of the frontal and the left and right **(Fig. 3)** parietal bones, covering more than two-thirds of the inner surfaces. The squamous part of the occipital **(Fig. 2)**and temporal bones, and the left and right greater wings of the sphenoid bone also revealed multifocal PAs. Shallow APDIs were noted on the squamous part of the frontal bone and in the left and right parietal bones, indicating eICP secondary to TBM[26]. The postcranial skeleton showed no signs of bony changes probably associated with TB. The recorded cause of death of Terry No. 1222 supports the tuberculous origin of the observed endocranial alterations.

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[21] Schultz, 1993, 1999, 2001, 2003.

[22] Schultz, 1993, 2001, 2003.

[23] Kelley & Micozzi, 1984; Roberts *et al.*, 1994; Santos & Roberts, 2001, 2006; Maczel, 2003; Matos & Santos, 2006; Giacon, 2008; Mariotti *et al.*, 2015.

[24] Schultz 1999, 2001, 2003 and *Schultz&Schmidt-Schultz* 2015.

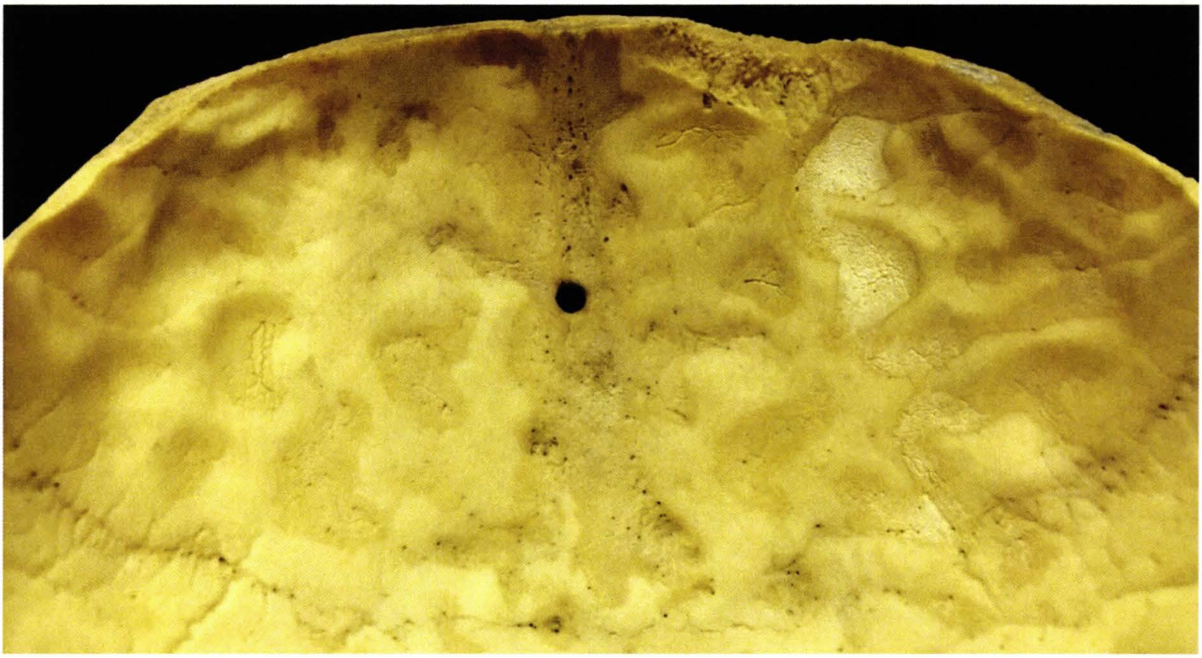
[25] Schultz, 1993, 1999, 2001, 2003.

[26] Schultz, 1993, 2001, 2003.

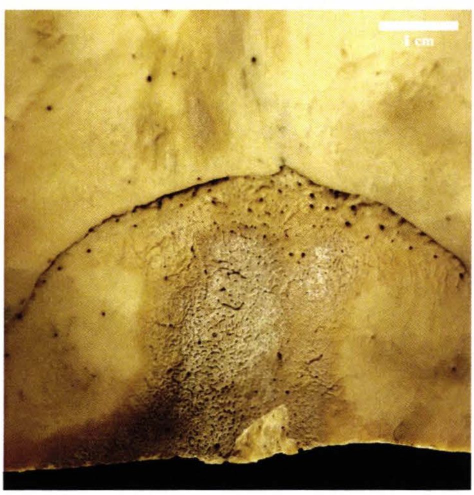
Figure 2: Multifocal GIs and PAs on the squamous part of the occipital bone (Terry No. 1222, 28-year-old, female, pulmonary TB).

Figure 3: Multifocal ABVIs covered by PAs on the inner surface of the right parietal bone (Terry No. 1222, 28-year-old, female, pulmonary TB).

The skeletal remains of **Terry No. 1322** – a 34-year-old male whose morgue record states pulmonary TB as the cause of death – displayed numerous pathological bony changes that probably resulted from tuberculosis. In the skull, deep APDIs were registered all over the inner surface of the skullcap **(Fig. 4A)**and skull base, probably referring to eICP due totuberculous involvement of the central nervous system[27]. Furthermore, non-specific vestiges of haemorrhagic and/or inflammatory meningeal processes – namely multifocal, small, serpentine branching ABVIs accompanied by slight PAs[28] – were detected in the deep DIs and along the sagittal suture in the frontal **(Fig. 4A)** and the left and right parietal bones. Multifocal ABVIs covered by thin layers of newly formed bone (PAs) were also noted along the sagittal **(Fig. 4B–C)** and left transverse **(Fig. 4C)**sinuses in the occipital bone, and along the left sigmoid sinus **(Fig. 4C)** in the left temporal bone. Moreover, unifocal PAs occurred on the squamous part of the right temporal bone and on the left and right greater wings of the sphenoid bone.



A)



B)

C)

Figure 4: Multifocal ABVIs accompanied by PAs A) in the deep DIs on the frontal bone, B) along the sagittal sinus (occipital bone), and C) along the left transverse (occipital bone) and sigmoid (left temporal bone) sinuses(Terry No. 1322, 34-year-old, male, pulmonary TB).

Regarding the postcranial skeleton, three left side ribs (4^{th}–6^{th}) showed very slight PNBFs on the visceral surface of the vertebral (5^{th}–6^{th}) or sternal (4^{th}) end that may represent signs of an

[27] Schultz, 1993, 2001, 2003.

[28] Schultz, 1993, 1999, 2001, 2003.

inflammatory response secondary to pulmonary TB and/or TB pleurisy[29]. In the vertebral column, multiple, smooth-walled resorptive pits often connected by horizontal, superficial vascular channels were recognised on the lateral aspects of the thoracic (T3–12) and lumbar (L1–5) vertebral bodies, indicating early-stage skeletal TB[30]. Although the observed endocranial and postcranial bony changes are not pathognomonic features of TB, the cause of death of Terry No. 1322 supports their tuberculous origin.

Conclusions

In 1993, tuberculosis has been declared a global health threat by the World Health Organization (WHO, 1994). Despite significant advances in the fight against TB in the last few decades, it still presents a health emergency, especially in developing countries[31]. Therefore, a renewed interest and funding to the research of the disease and of its aetiological agents has sparked since the late 20th century to eliminate or at least control TB in the future[32]. The palaeopathological research of tuberculosis (essentially based upon the macromorphological diagnosis of the disease in ancient human remains) provides invaluable novel data on the different manifestations of TB and on the effects of the disease upon human mortality and morbidity in past populations[33].

Since the late 20th century, a number of studies[34] were performed on documented skeletal collections that have revealed a positive correlation between different types of tuberculosis and bony changes, but only the minority of them focused on endocranial alterations very likely associated with TB meningitis. Nevertheless, the establishment of a more reliable and accurate paleopathological diagnosis of TB and the assessment of a more relevant disease prevalence in human osteoarchaeological series require excessive scientific knowledge on the macromorphological diagnostics of different forms of tuberculosis, including TBM, that underlines the importance of the case studies presented in our paper.

The three example cases from the Terry Collection exhibit different types of endocranial alterations likely resulted from TBM in association with each other and/or with non-endocranial bony changes probably related to TB. Although most of the detected endocranial bony changes cannot be considered as pathognomonic vestiges of the disease, palaeopathologists can use them – with necessary circumspection – to diagnose TBM in osteoarchaeological series from the pre-antibiotic era, especially when they occur simultaneously with each other or in association with probable TB-related non-endocranial alterations. The recorded cause of death of the three selected specimens from the Terry Collection also supports the tuberculous origin of the observed endocranial and non-endocranial lesions. However, it must be noted that even though the morgue record of the aforementioned individuals states pulmonary TB as the cause of death, tuberculosis may not have been the only medical condition present in the specimens that could contribute to the development of bony changes in their skeleton. Moreover, there is always the possibility that an inaccurate cause of death was registered on the morgue record and/or death certificate of individuals from the Terry Collection. Therefore, palaeopathologists should be cautious when they identify TBM in human osteoarchaeological material from the pre-antibiotic era on the basis of the above-mentioned endocranial lesions.

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[29] Kelley & Micozzi, 1984; Roberts *et al.*, 1994; Santos & Roberts, 2001, 2006; Maczel, 2003; Matos & Santos, 2006; Giacon, 2008; Mariotti *et al.*, 2015.

[30] Ménard, 1888; Baker, 1999; Maczel, 2003; Giacon, 2008; Mariotti *et al.*, 2015.

[31] WHO, 2018.

[32] Pálfi *et al.*, 2015; Pai *et al.*, 2016; WHO, 2018.

[33] Maczel, 2003; Santos & Roberts, 2006; Pálfi *et al.*, 2015.

[34] Kelley & Micozzi, 1984; Roberts *et al.*, 1994; Winland *et al.*, 1997; Santos & Roberts, 2001, 2006; Hershkovitz *et al.*, 2002; Maczel, 2003; Matos & Santos, 2006; Giacon, 2008; Mariotti *et al.*, 2015.

In summary, our three example cases provide palaeopathologists with a stronger basis for diagnosing TB meningitis in ancient human remains that reveal endocranial alterations resembling that of our cases; and therefore, with a more sensitive means of assessing the prevalence of TB in past populations.

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PROBABLE CASES OF TUBERCULOSIS FROM THE 10TH–11TH CENTURY AD CEMETERY OF EPERJES-IFJÚ GÁRDA TSZ. (CSONGRÁD COUNTY, HUNGARY)

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Abstract

In the palaeopathological practice, the assessment of the prevalence of tuberculosis (TB) in past human populations has traditionally relied upon the diagnosis of spinal TB and/or TB arthritis of the large, weight-bearing joints only. Since osteoarticular TB occurs in less than 2% of all patients with active TB today and – according to estimates – accounted for about 3–5% of all TB cases in prehistoric and historic times, it is difficult to assess the true prevalence of the disease in human osteoarchaeological material based only on the above-mentioned diagnostic criteria. To contribute to facilitating the establishment of a more reliable and accurate palaeopathological diagnosis of TB and the assessment of a more relevant disease prevalence in past human populations, a number of studies were performed on osteoarchaeological series and documented skeletal collections since the late 20th century that have revealed a positive correlation between different types of TB and subtle bony changes (e.g., vertebral hypervascularisation, periosteal new bone formations on the visceral surface of ribs, and endocranial alterations). Although most of the aforementioned lesions cannot be considered as specific signs of TB, palaeopathologists can still use them – with necessary circumspection – to diagnose the disease in osteoarchaeological material, especially when they simultaneously occur with each other. To improve our knowledge on the occurrence of TB and to estimate the prevalence of the disease in the 10th–11th century AD population of Eperjes–Ifjú Gárda Tsz., a detailed macroscopic investigation was carried out on the human bone remains from the cemetery that focused on the detection of all bony alterations probably related to different forms of TB. The aim of our study is to discuss in detail the five cases from Eperjes–Ifjú Gárda Tsz. that exhibited lesions likely associated with tuberculosis. Our results provide novel data regarding the palaeoepidemiology of the disease in the 10th–11th century AD of Hungary.

Introduction

Using modern medical knowledge, palaeopathologists attempt to establish a retrospective diagnosis of prehistoric and historic cases with tuberculosis by macroscopically identifying pathological conditions (*e.g.*, spinal TB and TB arthritis of the large, weight-bearing joints) in skeletons of people lived in the past that may be related to the disease[1]. However, utilisation of modern diagnostic criteria for tuberculosis in the palaeopathological practice may not be appropriate, since on

[1] Santos & Roberts, 2006; Mariotti *et al.*, 2015.

the one hand, probable TB-related bony changes observed in recent cases may differ from those of detectable in ancient human bone remains, due in part to the introduction of antibiotics in the treatment of tuberculosis[2]. On the other hand, in modern medical TB cases, bony changes cannot be surveyed with macromorphological methods but with medical imaging techniques (*e.g.*, X-ray radiography, computed tomography, and magnetic resonance imaging) only; nevertheless, subtle bony alterations may be impossible to be visualised by the latter ones[3]. Therefore, they are not relevant to the diagnosis of tuberculosis in recent cases and are not described as diagnostic criteria for the disease by physicians in the modern medical literature, even if they can be potentially important elements of TB identification for palaeopathologists[4]. Furthermore, the assessment of TB prevalence in past human populations has traditionally relied upon the palaeopathological diagnosis of spinal TB and/or TB arthritis of the large, weight-bearing joints only[5]. Since osteoarticular TB occurs in less than 2% of all patients with active tuberculosis and according to estimates, accounted for approximately 3 to 5% of all TB cases in prehistoric and historic times, it is difficult to assess the true prevalence of the disease in human osteoarchaeological material from the pre-antibiotic era based only on the above-mentioned diagnostic criteria[6].

To contribute to facilitating the establishment of a more reliable and accurate palaeopathological diagnosis of TB and the assessment of a more relevant disease prevalence in past human populations, a number of palaeopathological and palaeomicrobiological studies[7] were performed on osteoarchaeological series and documented skeletal collections since the late 20th century that have revealed a positive correlation between different types of tuberculosis (*e.g.*, skeletal TB, pulmonary TB and/or TB pleurisy, and TB meningitis) and subtle bony alterations, namely vertebral hypervascularisation, periosteal new bone formations (PNBFs) on the visceral surface of ribs and on the shaft of short and long tubular bones, and endocranial alterations (*i.e.*, abnormally pronounced digital impressions (APDIs); periosteal appositions (PAs); abnormal blood vessel impressions (ABVIs), including *serpens endocrania symmetrica*; and granular impressions (GIs)). Although most of the aforementioned bony changes cannot be considered as pathognomonic features of TB, palaeopathologists can still use them – with necessary circumspection – to diagnose the disease in osteoarchaeological material from the pre-antibiotic era, especially when they simultaneously occur with each other. Therefore, the utilisation of these criteria provide palaeopathologists with a stronger basis for identifying historic and prehistoric TB cases and with a more sensitive means of assessing the prevalence of the disease in past human populations.

To improve our knowledge on the occurrence of different manifestations of tuberculosis and to estimate the prevalence of the disease in the 10th–11th century AD population of Eperjes–Ifjú Gárda Tsz., a detailed macroscopic investigation was performed on the human bone remains from the cemetery that focused on the detection of all bony alterations probably related to TB. The aim of our study is to discuss in detail the five cases from Eperjes–Ifjú Gárda Tsz. that exhibited lesions likely associated with tuberculosis.

[2] Roberts *et al.*, 1994; Santos & Roberts, 2001, 2006; Matos & Santos, 2006.
[3] Roberts *et al.*, 1994; Santos & Roberts, 2001.
[4] Santos & Roberts, 2001, 2006; Matos & Santos, 2006.
[5] Kelley & Micozzi, 1984; Roberts *et al.*, 1994; Santos & Roberts, 2001, 2006; Matos & Santos, 2006; Pálfi *et al.*, 2012.
[6] Kelley & Micozzi, 1984; Roberts *et al.*, 1994; Pálfi *et al.*, 2012; Mariotti *et al.*, 2015.
[7] Ménard, 1888; Kelley & Micozzi, 1984; Schultz, 1993, 1999, 2001, 2003; Roberts *et al.*, 1994; Templin & Schultz, 1994; Teschler-Nicola *et al.*, 1994, 2015; Jankauskas & Schultz, 1995; Winland *et al.*, 1997; Rothschild & Rothschild, 1998, 1999; Baker, 1999; Jankauskas, 1999; Haas *et al.*, 2000; Santos & Roberts, 2001, 2006; Hershkovitz *et al.*, 2002; Maczel, 2003; Matos & Santos, 2006; Giacon, 2008; Pálfi *et al.*, 2012; Mariotti *et al.*, 2015; Masson *et al.*, 2015; Molnár *et al.*, 2015; Schultz & Schmidt-Schultz, 2015; Spekker, 2018

Materials & Methods

The skeletal material for this paper derives from the archaeological site of Eperjes–Ifjú Gárda Tsz. that is located in Csongrád county, Southeastern Hungary. The excavation was carried out in two phases (1969 and 1970) under the direction of *Csanád Bálint*, and a total of 25 burials were unearthed[8]. On the basis of the grave goods, the cemetery was dated back to the 10th–11th century AD[9]. The human bone remains from the Eperjes–Ifjú Gárda Tsz. site are currently curated in the Department of Biological Anthropology at the University of Szeged (Szeged, Hungary). It must be noted that, according to the information found in the archaeological documentation and in the inventory books of the Department,there is a significant difference between the number of burials discovered in the cemetery (N=25) and the number of skeletons (N=51) considered to belong to the site. Although the exact archaeological origin of about half of the 51 skeletons cannot be ascertained, all of them were included into the macroscopic investigation, since they can provide invaluable novel information regarding the different manifestations of tuberculosis in past populations of Hungary. (Grave numbers with uncertain origin are labelled with a "?".)

The examination of the 51 skeletons was performed using standard macromorphological methods of bioarchaeology. Before the palaeopathological investigation of the series, the sex and age at death of individuals[10] and the qualitative and quantitative state of preservation of the observable bone remains (3-level scale: 1) good, 2) intermediate, and 3) poor) were also recorded. As for the palaeopathological examination, the macroscopic evaluation of the 51 skeletons focused on the detection of bony alterations probably related to different forms of TB. These are the following:

- Bony changes indicative of osteoarticular TB (osteolytic or erosive vertebral lesions, collapse or fusion of the vertebral bodies, vertebral hypervascularisation, cortical remodelling and reactive new bone formation on the vertebral surfaces, signs of osteomyelitis of the extra-spinal bones, and destruction, subluxation or dislocation of the intervertebral or extra-spinal joints)[11];
- Lesions suggestive of pulmonary TB and/or TB pleurisy (periosteal new bone formations (PNBFs) on the visceral surface of ribs, erosive costal changes, and signs of diffuse, symmetrical periostitis on the diaphysis of short and long tubular bones)[12]; and
- Endocranial alterations likely associated with TBM (APDIs, PAs, ABVIs, and GIs)[13].

All bone remains of the 51 specimens from the 10th–11th century AD cemetery of Eperjes–Ifjú Gárda Tsz. were macromophologically evaluated. For each surveyed individual, detailed written and pictorial descriptions of all observed bony alterations likely associated with TB were made on a data collection sheet.In our paper, the following five skeletons were selected for discussion in detail, as they show probableTB-related bony changes:

- **Grave No. 4A (inventory No.13050)**: a c. 14-year-old (*Infantia 2*) child with indeterminable sex. The skeleton is well-preserved (only the facial bones, the short tubular bones of the hands and feet, the two patellae, the 7th cervical vertebra, and the body of the sternum are missing) and the qualitative state of preservation of the observable bone remains is intermediate;

[8] Bálint, 1970, 1971.

[9] Bálint, 1971.

[10] Schour & Massler, 1941; Nemeskériet *al.*, 1960; Éry *et al.*, 1963; Vlček, 1974; Stloukal &Hanâkovâ, 1978; Brothwell, 1981; Ubelaker, 1984; Loth & Işçan, 1989.

[11] Aufderheide & Rodríguez-Martín, 1998; Baker, 1999; Maczel, 2003; Ortner, 2003, 2008; Giacon, 2008; Mariotti *et al.*, 2015.

[12] Mensforth *et al.*, 1978; Kelley & Micozzi, 1984; Roberts *et al.*, 1994; Winland *et al.*, 1997; Rothschild & Rothschild, 1998, 1999; Santos & Roberts, 2001, 2006; Hershkovitz *et al.*, 2002; Maczel, 2003; Matos & Santos, 2006; Giacon, 2008; Mariotti *et al.*, 2015

[13] Mensforth *et al.*, 1978; Schultz, 1993, 1999, 2001, 2003; Hershkovitz *et al.*, 2002; Maczel, 2003; Lewis, 2004; Schultz & Schmidt-Schultz, 2015; Spekker, 2018.

• **Grave No. 13 (inventory No. 13061)**: a c. 10–12-year-old (*Infantia 2*) child with indeterminable sex. Both the qualitative and quantitative state of preservation of the skeleton are intermediate;

• **Grave No. 35? (inventory No. 13082)**: a middle-aged (*Maturus*) male, whose skeleton is very fragmentary: only the skull bones, and the long tubular bones of the lower and upper limbs are observable. Overall, the qualitative state of preservation of the bone remains is intermediate;

• **Grave No. 37? (inventory No. 13083)**: a c. 15–18-year-old (*Juvenis*) juvenile with indeterminable sex. Both the qualitative and quantitative state of preservation of the skeleton are good; and

• **Stray find 2 (no inventory No.)**: a c. 25–30-year-old (*Adultus*) male, whose skeleton is very fragmentary: only the left temporal bone, the long tubular bones of the left upper limb, the two hip bones and femora, the right patella, the lumbar vertebrae, and a few rib fragments are observable. Overall, the qualitative state of preservation of the bone remains is poor.

Results & Discussion

Grave No. 4A (inventory No. 13050):

The skeleton of grave No. 4A – a c. 14-year-old child with indeterminable sex – displayed numerous pathological bony changes that very likely resulted from tuberculosis. In the skull, deep APDIs were registered all over the inner surface of the skullcap **(Fig. 1)**, probably referring to elevated intracranial pressure (eICP) due totuberculous involvement of the central nervous system[14]. Furthermore, GIs – described by *Schultz*[15] and *Schultz&Schmidt-Schultz*[16] as pathognomonic features of TB meningitis (TBM) – were detected on the endocranial surface of the squamous part of the frontal **(Fig. 2A)** and occipital bones. Besides the above-mentioned lesions very likely associated with TBM, the left orbit exhibited signs of porotic *cribra orbitalia* **(Fig. 2B)**. (Due to a *post-mortem* injury, the right orbit cannot be examined.) Although *cribra orbitalia* is not a specific signs of TB, it was commonly noted in cases with infectious conditions, including tuberculosis[17].

Figure 1: APDIs on the inner surface of the squamous part of the frontal bone **(grave No. 4A, *Infantia 2*, indeterminable sex).**

[14] Schultz, 1993, 2001, 2003.

[15] Schultz, 1999, 2001, 2003

[16] *Schultz&Schmidt-Schultz* 2015

[17] Stuart-Macadam, 1989; Blondiaux *et al.*, 2015.

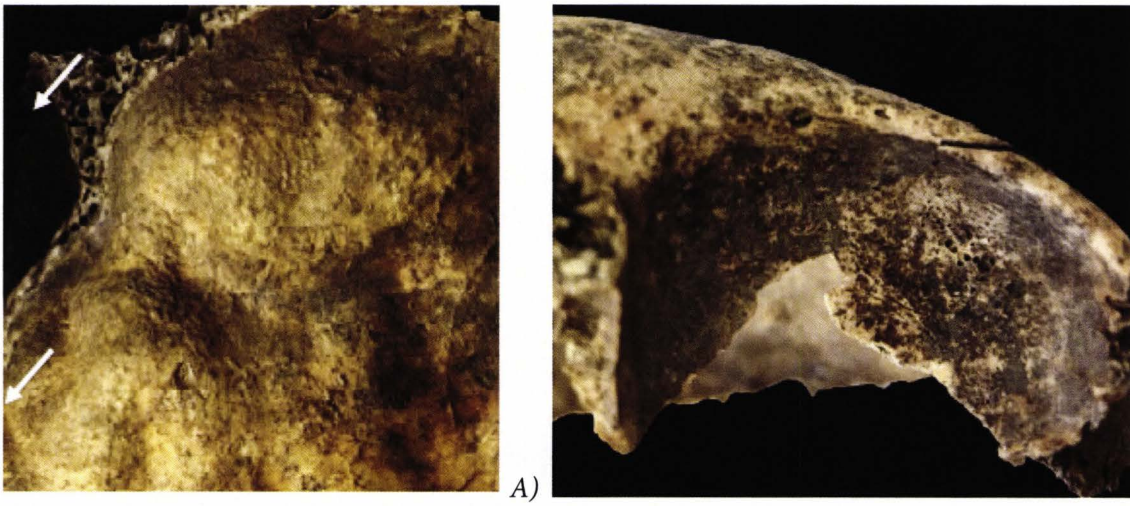


Figure 2: A) GIs on the inner surface of the left side of the squamous part of the frontal boneand B) signs of porotic cribra orbitalia *in the left orbit* **(grave No. 4A, *Infantia 2*, indeterminable sex).**

Regarding the postcranial skeleton of grave No. 4A, the vertebral column exhibited signs of hypervascularisation in the form of multiple, smooth-walled resorptive pits often connected by horizontal, superficial vascular channelson the anterior and/or lateral aspects of the thoracic (T2–12) **(Fig. 3A)** and lumbar (L1–5) **(Fig. 3B)** vertebral bodies. Signs of hypervascularisation– possibly referring to early-stage skeletal TB[18] – were also recognised on the ventral surface of the sacrum.

Although most of the cranial and postcranial bony changes observed in the skeleton of grave No. 4A are not specific signs of TB, they occurred in association with each other; and therefore, their tuberculous origin cannot be excluded.

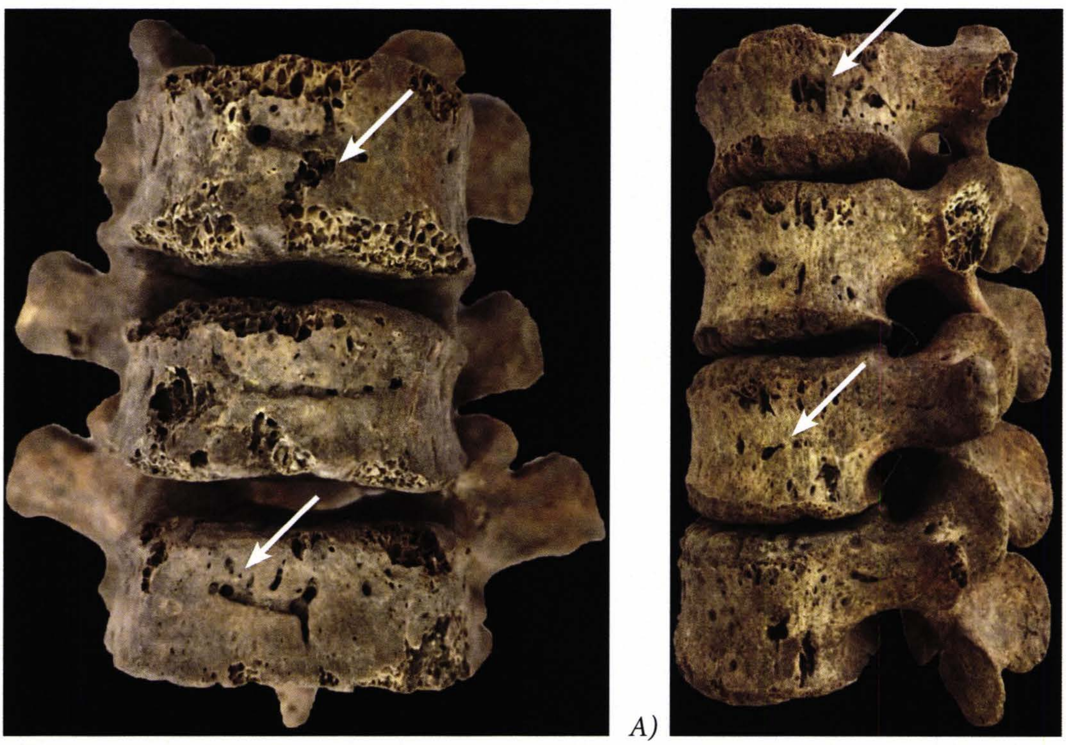
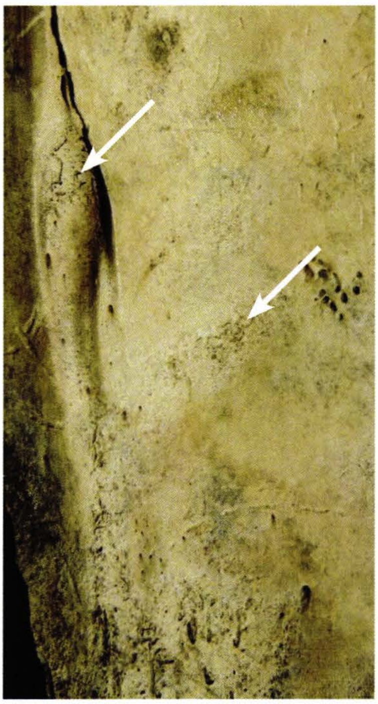


Figure 3: A) abnormal horizontal, superficial vascular channels on the anterior aspect of the T2–4 vertebral bodies and B) signs of hypervascularisation on the left lateral aspect of the L1–4 vertebral bodies **(grave No. 4A, *Infantia* 2, indeterminable sex).**

[18] Ménard, 1888; Baker, 1999; Maczel, 2003; Giacon, 2008; Mariotti *et al.*, 2015.

Grave No. 13 (inventory No. 13061):

Despite the poor state of preservation of the observable bone remains, two different types of endocranial alterations probably associated with TB meningitis were recorded in the skull of grave No. 13 (a 10–12-year-old child with indeterminable sex).The squamous part of the frontal bone (particularly along the sagittal sinus) **(Fig. 4A)** exhibited multifocal, small, serpentine branching ABVIs and patches of PAs that are considered as non-specific vestiges of haemorrhagic and/or inflammatory meningeal processes in the palaeopathological literature[19]. Moreover, ABVIs were detected on the two parietal bones and PAs were noted on the squamous part,as well as along the sigmoid sinus, of the left temporal bone. Besides the aforementioned endocranial lesions, signs of porotic *cribra orbitalia*– a stress indicator that often accompanies bony changes related to different infectious diseases, such as TB – were registered in both orbits[20].



A)

B)

Figure 4: A) PAs and ABVIs along the sagittal sinus on the inner surface of the frontal boneand B) circumferential, multiple, smooth-walled pits connected by horizontal vascular impressions on the anterior aspect of the lower thoracic vertebral bodies (lateral view) **(grave No. 13, *Infantia 2*, indeterminable sex).**

In the postcranial skeleton, the vertebral column and the two femora showed pathological bony changes that may be associated with TB. In the thoracic spine, multiple, smooth-walled resorptive pits often connected by horizontal, superficial vascular channels were recognised on the anterior and/or lateral aspects of the vertebral bodies(T1–12) **(Fig. 4B)**, indicating early-stage skeletal TB[21]. The cervical (C3–7) and lumbar (L1–5) regions, as well as the ventral surface of the sacrum, also exhibited signs of hypervascularisation. Furthermore, slight PNBFs were detected on the medial **(Fig. 5)** and posterior surfaces of the left femur and on the posterior surface of the right femur **(Fig. 6)** (all along the shaft). Although PNBFs predominantly affecting the shaft of short and long tubular bones cannot be considered as specific signs of TB, similar to *cribra orbitalia*, they represent

[19] Schultz, 1993, 1999, 2001, 2003.

[20] Stuart-Macadam, 1989; Blondiaux *et al.*, 2015.

[21] Ménard, 1888; Baker, 1999; Maczel, 2003; Giacon, 2008; Mariotti *et al.*, 2015.

stress indicators that were frequently registered in cases with infectious conditions, including tuberculosis[22].

The cranial and postcranial bony changes observed in the skeleton of grave No. 13 are not pathognomonic features of TB; nevertheless, their co-occurrence supports their tuberculous origin.

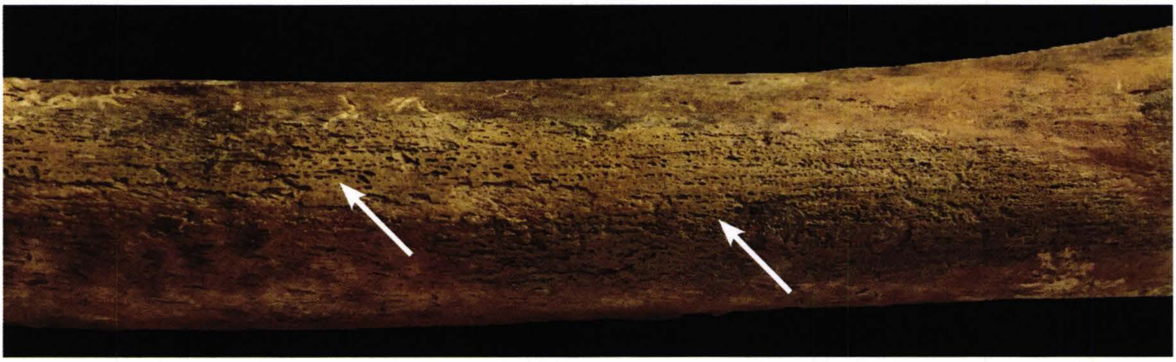


Figure 5: Slight PNBFs on the medial surface of the diaphysis of the left femur **(grave No. 13, *Infantia 2,* indeterminable sex).**

Figure 6: Signs of very slight periostitis on the posterior surface of the diaphysis of the right femur **(grave No. 13, *Infantia 2*, indeterminable sex).**

Grave No. 35? (inventory No. 13082):

In the skeleton of grave No. 35? – a middle-aged male – pathological bony changes that may be attributed to tuberculosis were registered both in the cranial and postcranial elements.In the skull, shallow APDIs were noted all over the inner surface of the skullcap **(Fig. 7)**, indicating eICP very likely due to hydrocephalus that may be associated with TBM[23]. Moreover, non-specific vestiges of haemorrhagic and/or inflammatory meningeal processes – namely multifocal, small, serpentine branching ABVIs[24] – were also detected on the endocranial surface of the frontal **(Fig. 7)** and the two parietal bones **(Fig. 8A)** (especiallyalong the sagittal suture). Multifocal ABVIs were also recorded on the inner surface of the occipital bone (particularly along the sagittal and transverse sinuses).Besides the aformentioned endocranial alterations (*i.e.*, APDIs and ABVIs) that are not specific signs of TB meningitis, GIs – described by *Schultz*[25] and *Schultz&Schmidt-Schultz*[26] as pathognomonic features of the disease – were registered on the squamous part of the occipital and the two temporal bones, and on the right greater wing of the sphenoid bone **(Fig. 8B)**.

[22] Mensforth *et al.*, 1978; Pálfi, 2002.

[23] Schultz, 1993, 2001, 2003; Paul *et al.*, 2013.

[24] Schultz, 1993, 1999, 2001, 2003.

[25] *Schultz* 1999, 2001, 2003.

[26] *Schultz&Schmidt-Schultz* 2015.

Figure 7: Shallow APDIs and ABVIs on the endocranial surface of the squamous part of the frontal bone **(grave No. 35?, *Maturus*, male).**

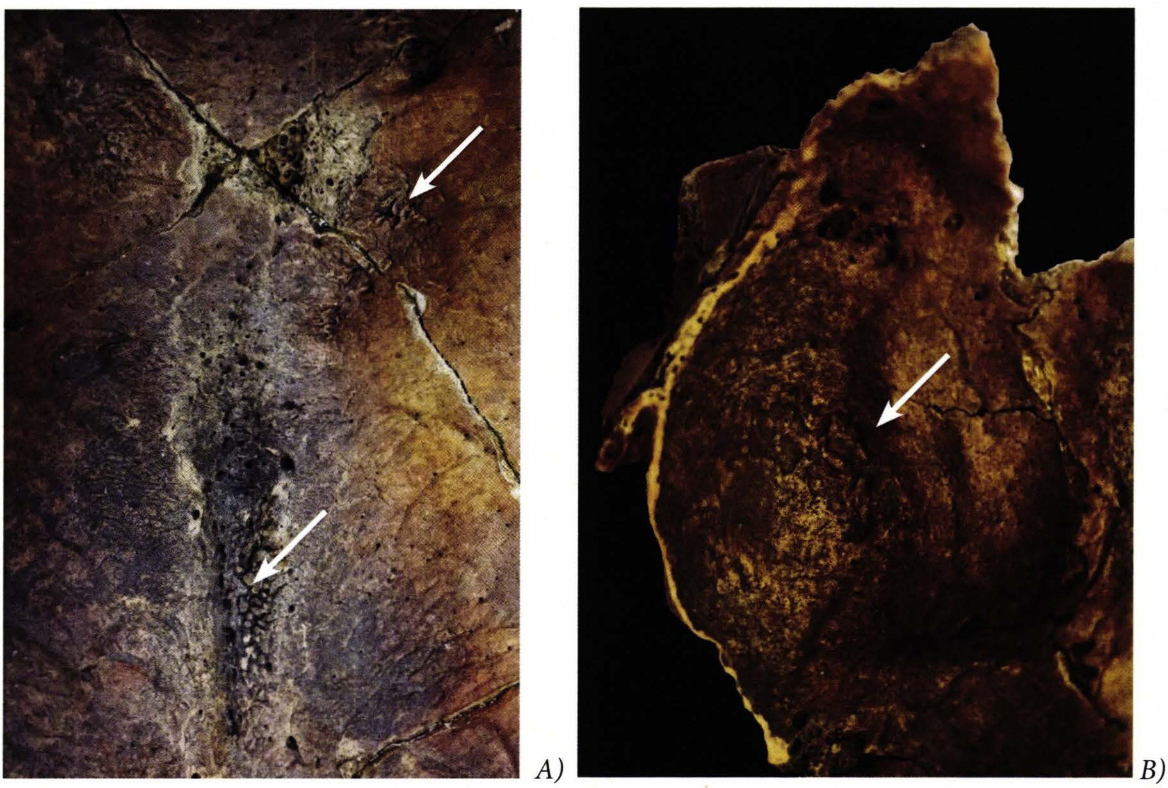


Figure 8: A) ABVIs on the endocranial surface of the parietal bones, along the sagittal sutureand B) GIs on the endocranial surface of the right greater wing of the sphenoid bone **(grave No. 35?, *Maturus*, male).**

In the postcranial skeleton, the medial and lateral surfaces of both femora **(Fig. 9)** and tibiae **(Fig. 10)** (all along the shaft), the medial surface of the left humerus and right ulna(particularly on the middle portion of the shaft), the lateral surface of the proximal epiphysis of the left ulna **(Fig. 11)**, the anterior surface of the right radius (predominantly on the distal portion of the shaft), and the posterior surface of the 5th metatarsal (particularlyon the distal portion of the shaft) exhibited slight PNBFs. Diffuse, bilateral, symmetrical PNBFs predominantly affecting the distal and periarticular parts of the shaft of short and long tubular bones are characteristic features of hypertrophic pulmonary osteopathy (HPO). The exact aetiology of HPO is still unknown;however, the secondary form of the disease is frequently associated with pulmonary (*e.g.*, pulmonary TB and lung cancer), as well as non-pulmonary (*e.g.*, inflammatory bowel disease and cirrhosis) conditions[27]. Following examination of skeletons of known cause of death from modern identified skeletal collections, diffuse, bilateral, symmetrical PNBFs were described as not specific but probable signs of tuberculosis, as they occurred more frequently in individuals reported to have died of TB than in specimens identified to have died of non-TB causes[28].

Although most of the cranial and postcranial bony changes observed in the skeleton of grave No. 35? are not specific signs of TB, they occurred in association with each other; and therefore, their tuberculous origin cannot be excluded.

Figure 9: PNBFs on the anterior surface of the diaphysis of the left femur **(grave No. 35?, *Maturus*, male).**

Figure 10: Signs of periostitis on the medial surface of the diaphysis of the right tibia **(grave No. 35?, *Maturus*, male).**

27 Kelly *et al.*, 1991; Assis *et al.*, 2011; Yap *et al.*, 2017.

28 Mensforth *et al.*, 1978; Kelly *et al.*, 1991; Winland *et al.*, 1997; Rothschild & Rothschild, 1998, 1999; Santos & Roberts, 2001; Hershkovitz *et al.*, 2002; Assis *et al.*, 2011.

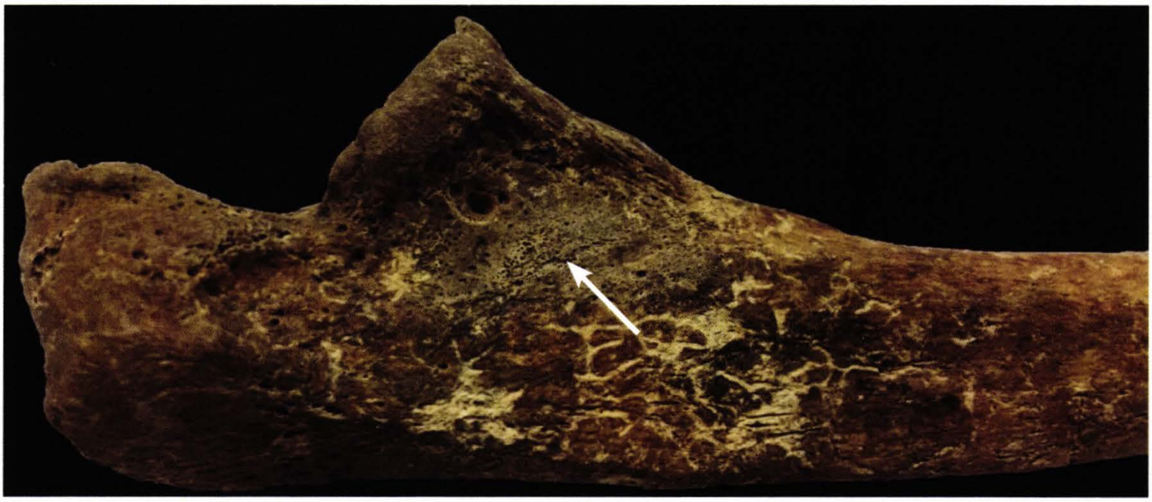


Figure 11: PNBFs on the lateral surface of the proximal epiphysis of the left ulna **(grave No. 35?, *Maturus*, male).**

Grave No. 37? (inventory No. 13083):

Both the cranial and postcranial elements of grave No. 37? – a juvenile (c. 15–18-year-old) individual with indeterminable sex –,showed different types of bony changes that may resulted from tuberculosis. As for the skull, deepDIs were noted on the endocranial surface of the squamous part of the frontal bone **(Fig. 12)**, referring to eICP probably secondary to TB meningitis[29]. Furthermore, endocranial lesions that resemble multifocal GIs – described by *Schultz*[30] and *Schultz&Schmidt-Schultz*[31] (2015)

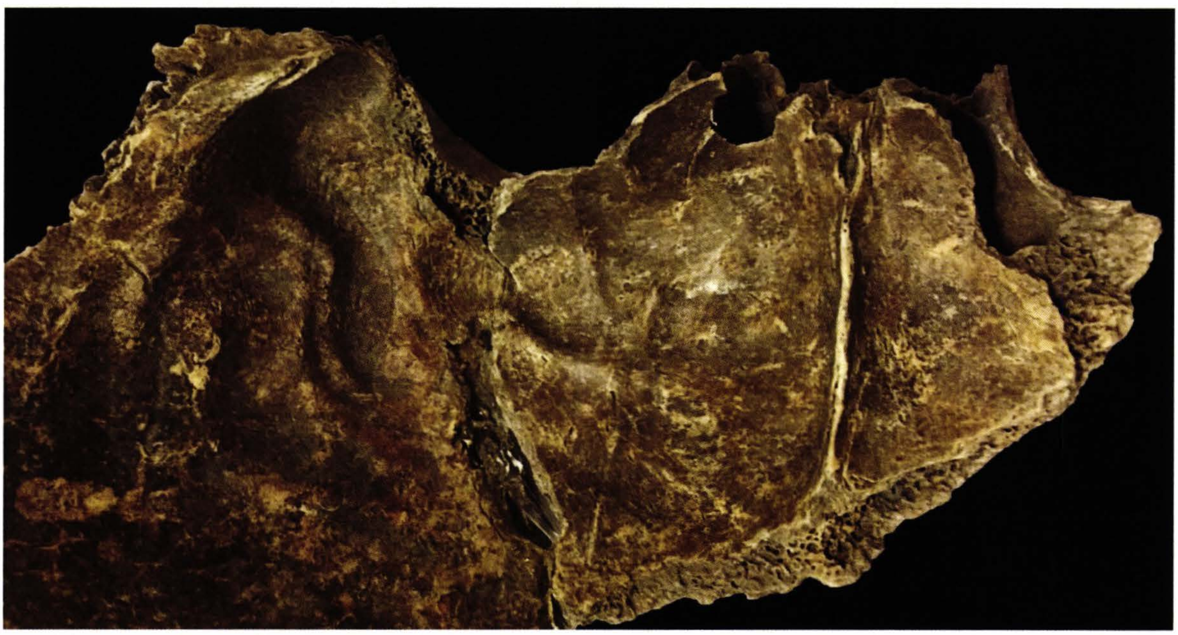


Figure 12: APDIs on the right side of the squamous part of the frontal bone **(grave No. 37?, *Juvenis*, indeterminable sex).**

as pathognomonic signs of TBM, since representing pressure atrophy of the tubercles – were detected on both sides of the squamous part of the frontal bone **(Fig. 13)**, in the right parietal bone along the squamous suture, on the squamous part of bothtemporal bones, and on both greater

[29] Schultz, 1993, 2001, 2003; Paul *et al.*, 2013.

[30] *Schultz,* 1999, 2001, 2003.

[31] *Schultz&Schmidt-Schultz,* 2015.

wings of the sphenoid bone. Nonetheless, because of the poor state of preservation of the observable bone remains, the *post-mortem* origin of certain detected alterations cannot be excluded.Besides the above-mentioned endocranial lesions, the porotic type of *cribra orbitalia* was registered in the right orbit (**Fig. 14**) (The left orbit is missing *post-mortem*). *Cribra orbitalia*is not a specific signs of TB; nonetheless, it commonly occurs in association with bony changes related to infectious conditions, such as tuberculosis[32].

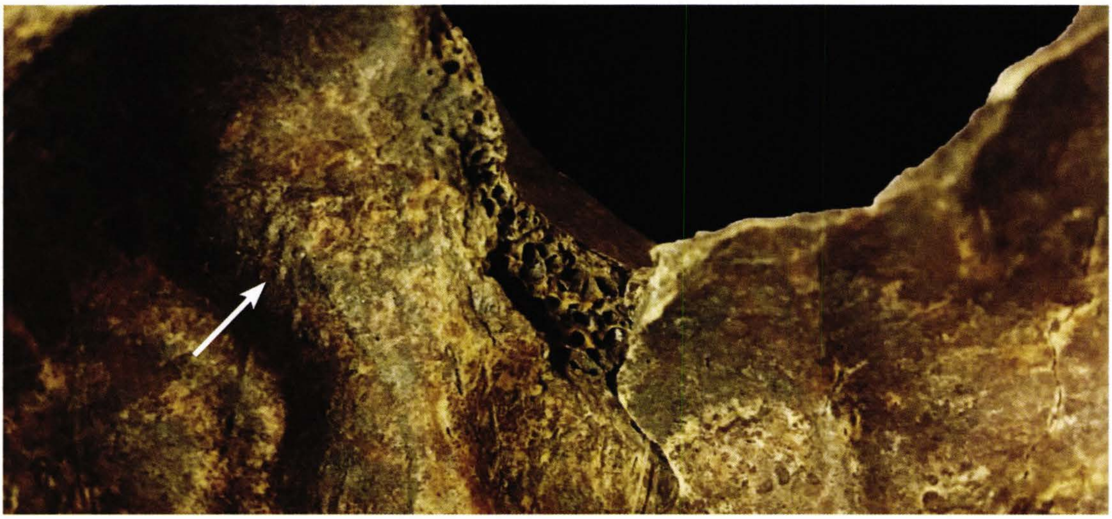


Figure 13: GIs on the left side of the frontal bone **(grave No. 37?, *Juvenis*, indeterminable sex).**

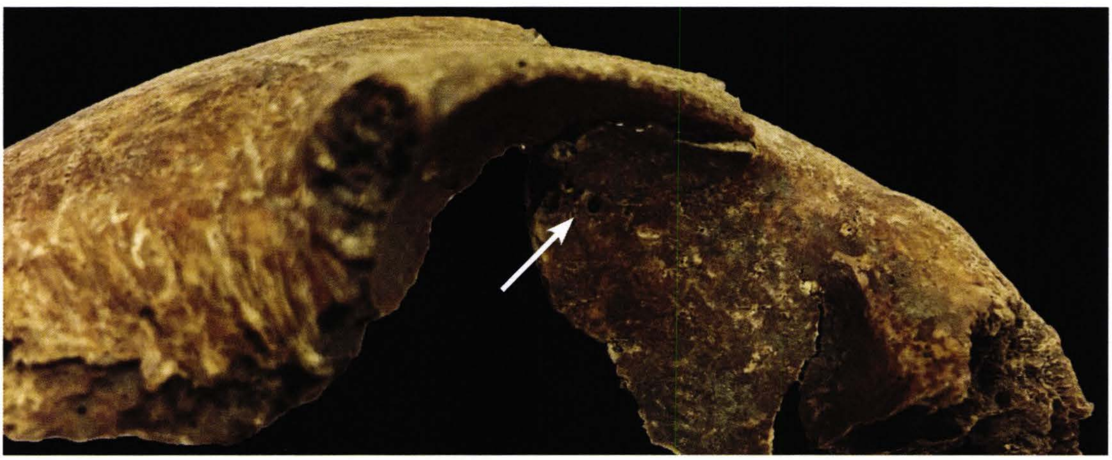


Figure 14: Cribra orbitalia (porotic type) in the right orbit **(grave No. 37?, *Juvenis*, indeterminable sex).**

Regarding the postcranial elements, the vertebral column exhibited signs of hypervascularisation in the form of circumferential pitting on the anterior and/or lateral aspects of the upper thoracic(T1–6) region and in the form of multiple, smooth-walled resorptive pits often connected by horizontal, superficial vascular channels in the lower thoracic (T7–12) region **(Fig. 15)**. The lateral aspects of the lumbar (L1–5) vertebral bodies and the ventral surface of the sacrum also exhibited signs of hypervascularisation, possibly referring to early-stage skeletal TB[33].

Although most of the cranial and postcranial bony changes observed in the skeleton of grave No. 37? are not pathognomonic features of TB, their co-occurrence supports their tuberculous origin.

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[32] Stuart-Macadam, 1989; Blondiaux *et al.*, 2015.

[33] Ménard, 1888; Baker, 1999; Maczel, 2003; Giacon, 2008; Mariotti *et al.*, 2015.

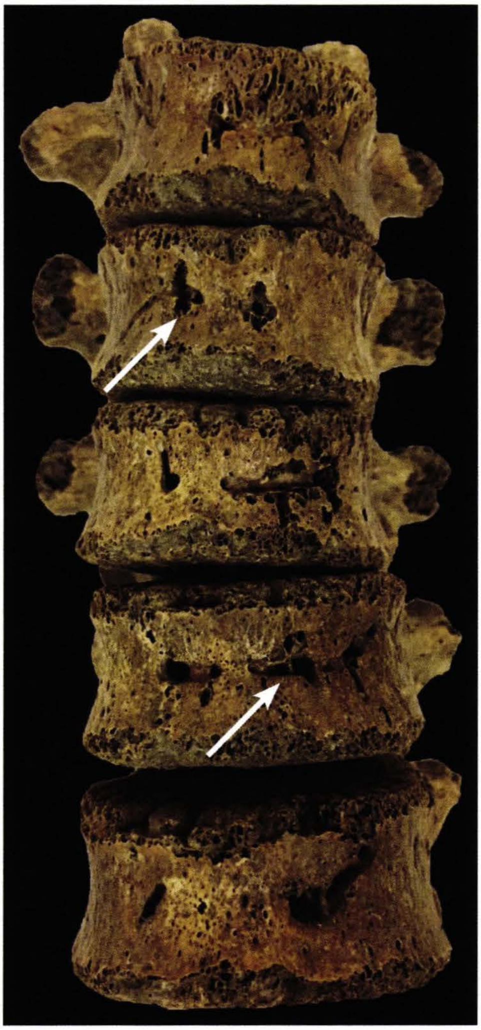

Figure 15: Circumferential, multiple, smooth-walled pits connected by horizontal vascular impressions on the A) anterior and B) left lateral aspects of the T7–11 vertebrae **(grave No. 37?, *Juvenis*, indeterminable sex).**

Stray find 2 (no inventory No.):

In the skeleton of stray find 2 – a young adult (c. 25–30-year-old) male –, pathological bony changes that may be ascribed to tuberculosis were registered in a left rib fragment: on the visceral surface of the costal angle, thin layers of PNBFs **(Fig. 16)** were detected. During the macroscopic evaluation of the observable bone remains, no other lesions probably related to TB were recorded in the cranial and postcranial elements of stray find 2.

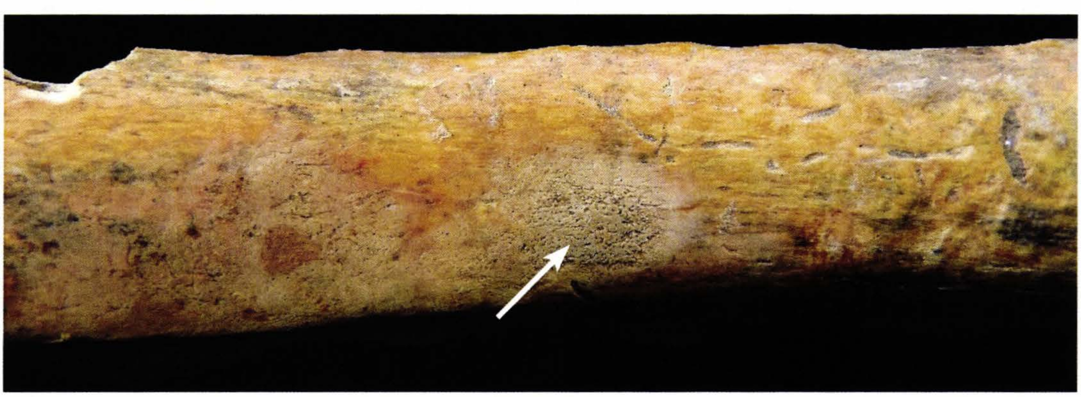

Figure 16: Thin layers of PNBFs on the visceral surface of the costal angle of a left rib fragment **(stray find 2, *Adultus*, male).**

PNBFs affecting the visceral surface of ribs were associated with TB following examination of skeletons of known cause of death from modern identified skeletal collections (*e.g.*, *Hamann–Todd Human Osteological Collection*, *Robert J. Terry Anatomical Skeletal Collection*, and *Coimbra Identified Skeletal Collection*), as they occurred more frequently in individuals reported to have died of TB than in specimens identified to have died of non-TB causes[34]. Nevertheless, several pulmonary diseasesother than TB, as well as non-pulmonary ones (*e.g.*, acute lobar pneumonia, bronchiectasis, metastatic carcinoma, pyogenic osteomyelitis, syphilis, and actinomycosis), can also stimulate the formation of PNBFs on the inner surface of ribs[35].

Although the aforementioned PNBFs cannot be considered as pathognomonic features of TB, the tuberculous origin of the lesions observed in the skeleton of stray find 2 cannot be excluded, since other individuals from the examined cemetery also exhibited bony changes probably related to TB, implying the presence of the disease in the 10th–11th century AD population of Eperjes–Ifjú Gárda Tsz.

In summary, five cases showing pathological lesions likely associated with tuberculosis were identified during the macroscopic evaluation of skeletons from the 10th–11th century AD cemetery of Eperjes–Ifjú Gárda Tsz. In four out of the five cases, the co-occurrence of at least two types of the aforementioned alterations was detected. Although most of the recorded bony changes are not specific signs of TB, their association supports their tuberculous origin. Our results contribute to improving our knowledge regarding the occurrence of different manifestations of tuberculosis and the prevalence of the disease in the 10th–11th century AD of Hungary, since providing five new probable cases from this period.

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[34] Kelley & Micozzi, 1984; Roberts *et al.*, 1994; Santos & Roberts, 2001, 2006; Matos & Santos, 2006; Mariotti *et al.*, 2015.

[35] Kelley & Micozzi, 1984; Roberts *et al.*, 1994; Santos & Roberts, 2001, 2006; Matos & Santos, 2006; Mariotti *et al.*, 2015.

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SKELETAL REMAINS OF THE GEPID PERIOD IN THE GREAT HUNGARIAN PLAIN. LITERATURE REVIEW

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Keywords: *Gepids, Great Hungarian Plain, historical anthropology, craniometry, taxonomy, paleopathology*

Abstract
The present paper summarizes the anthropological information available so far regarding the population of the Carpathian Basin in the Gepid period, providing an overview of the metric and taxonomical data as well as of pathological alterations. This paper relies on the available publications and manuscripts, without attempting to be exhaustive.

Introduction

In attempting to carry out a biological reconstruction of historical populations, authors can follow different methods. These are including taxonomical assessment based on metric and morphological traits, various mathematical and statistical models of biodistance analysis, the evaluation of epigenetic variations, paleopathological analysis and molecular or isotopic investigations. Which method can be used, however, depends greatly on the state of preservation of the skeletal material and the number of available individuals.

The anthropological literature on specific periods often contains the general results of "classic" (age- and sex assessment, metric analysis) investigations regarding a particular series, but comprehensive analyses of entire periods based on populations of various sizes can also be found.

The aim of the present paper is to provide an approximate overview of the biological reconstruction of the population of the Gepid period. The anthropological characterization of this population is far from being complete despite the relatively large number of publications about it. Thus, the publication of any skeletal material is important, regardless the number of individuals and the state of preservation

The sources of the present paper are the descriptions of the skeletal material of the sites in published papers, theses, the Széchenyi grant (05/81) concerning the Gepids, and comprehensive works describing the entire period from a variety of perspectives. The literature consulted for this paper is primarily that concerned with the Great Hungarian Plain, however, due to the lack of representative samples, results from neighboring regions have also been taken into consideration.

The present paper does not aim to address the issue of the deformed skulls of the Gepids, since that has already been addressed in one paper[1] and two theses.[2]

[1] Bereczki and Marcsik 2006
[2] Szécsényi-Nagy, Anna: *A koponyatorzítás szokása a Kárpát-medencében, az V-VI. században, régészeti és antropológiai*

Literature review, published papers and manuscripts

1. The majority of the published studies present taxonomic analyses of metric and morphological characteristics of Gepid period skeletal material and address the well-known issue of artificial deformation.

The first such work was by János Gáspár,[3] examining skeletal material from Kiss Pál tanya, Hódmezővásárhely-Gorzsa, and establishing that the majority of this population belonged to Nordoid type, a minority of them were characterized as Ural-Altaic (belonging probably to the Mongolid group, or presumably to the Huns). Mixed types were also found, namely, the mixture of the Nordoid and Mongolid types, and an artificially deformed skull was also described by him. Later, Lajos Bartucz provided an account of the Gepid skulls of the Kiszombor-B cemetery.[4] He analyzed the population and the deformed skulls in detail. According to him, the Gepids of Kiszombor-B belonged to the Nordoid, Mediterranean, East European, and Turanid groups, and to the Mongolid and Paleo-Asian groups. He considered the Nordoid type to be the most characteristic for the males, and the East European for the females. He hypothesized that the Paleo-Asian and Turanoid (Mongolid and Mongoloid) elements can be connected to the Hun period component of the Gepid population. Of the 54 skulls, 21 are artificially deformed, and, according to the author, this was a tradition adopted from the Huns with whom they cohabitated.[5] The material from the 10 Gepid graves (late 5th to early 6th century), uncovered in the Lencsésdomb area of the village of Ártánd, near Biharkeresztes was examined by(?) The bones were very fragmentary and, therefore, unsuitable for taxonomic analysis. Feature6 yielded a deformed skull. Another cemetery was uncovered at Toldi útfél in Biharkeresztes (6th century),[6] in which skeletal material from 10 Gepid graves was identified. The bones werebadly preserved, cranial index could be estimated in one individual and was dolicomorphic.[7] At the Endrőd-Szujókereszt site, in addition to skeletons uncovered from Sarmatian graves, the grave of a Gepid male was also found (feature 91). The author provided the metric values of the skeleton.[8] The skeletal material uncovered around Békéscsaba, dated to various archeological periods, includes a skeleton of a Gepid male originating from the Gyula-Fövenyes site. The skull is dolichomorphic, taxonomically characterized as Nordoid-x.[9] Zsuzsa K. Zoffmann reported on two deformed skulls and additional skeletons uncovered at different times at the Hratkovci-Vranj (Sirmium) site from Serbia.[10] From the Viminacium site (Serbia) 94 Gepid (6th c.) skeletons were examined, of which 31 skulls were deformed. The author provided the metric data of the skulls.[11] Péter Zsolt Varga and his colleagues were able to carry out a cra-

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adatok alapján [Skull deformation in the Carpathian Basin in the 5th and 6th centuries: Archeological and anthropological data]. Thesis, Institute of Archeology, Eötvös Loránd University, Budapest, 2009. Miháczi-Pálfi, Anett: *Torzított koponyás temetkezések az Alföldön (a 4-5. század fordulójától a 8-9. század fordulójáig)* [Skull deformation in burials in the Great Hungarian Plain, from the turn of the 4th and 5th centuries to the turn of the 8th and 9th centuries]. Thesis, Department of Archeology, University of Szeged, 2013.

3 Gáspár 1931.

4 Bartucz 1936.

5 In a book published later, he described the Gepid skulls found in Kiszombor (Bartucz 1966, 247–260). Pál Lipták and Antónia Marcsik reexamined these skulls and concluded that the number of deformed skulls is lower (Lipták – Marcsik 1977, 42–43). In his book, Bartucz also described the deformed Gepid skulls from Szőreg (Bartucz 1966, 260–284), however, the results of the anthropological examination have not yet been published.

6 The two cemeteries were published by Mesterházy 2005.

7 Lipták – Marcsik 1977.

8 Pap 1983.

9 Farkas et al. 1991.

10 Zoffmann 1992; Zoffmann 1998.

11 Mikič 1999.

niometric evaluation of only 13 skulls from the 98 skeletons uncovered from the Szolnok-Szanda Gepid cemetery. From a taxonomic point of view, they were almost exclusively of the Europid type, among males the Nordoid-Cromagnoid and brachycranic types were revealed while in females Cromagnoid and Mediterranean types were characteristic.).[12] We also know more deformed skulls from the village of Tápé.[13]

2. The other, smaller, portion of the studies discusses diseases manifested in the skeletons in addition to providing a general anthropological description and noting the deformed skulls.

In the area of Rákóczifalva-Bivalytó, at the Rokkant föld I.3, and II. 4 sites, the skeletal remains of altogether 8 Gepid individuals were uncovered. The examined crania are long or medium (dolichocranic-mesocranic) and high (akrocranic, hypsicranic). Signs of deformation could be established in the case of 5 individuals. From a pathological point of view, osteoarthrosis (of the hip and shoulder joints) and mild type of porotic hyperostosis were discovered.[14] Similar anthropological elaboration was carried out in the 22 Gepid (5th–6th centuries) skeletal remains uncovered at Kál-Legelő III site. The study discusses in detail the metric, morphological, and taxonomic analysis as wellthe pathological cases, and the values of the two deformed skulls. Taxonomically they were of Europid ancestry (Nordoid, Cromagnoid), however, the deformed skulls have Mongolid ancestry.[15] The skeletal material of the Alba Iulia-Proprietatea Staicu Gepid cemetery is very fragmented, only one skull can be measured.[16] Developmental anomalies of the teeth and other disorders and osteoporosis are present to a significant degree. The postcranial bones exhibit considerable robusticity. In a monography about the ancient populations of Sirmium and the neighboring area, the anthropological characteristics of 34 skeletal remains from the 5th–6th centuries (called Germanic period), including their pathological alterations, were presented. In the examined remains one male skull was found to be deformed.[17]

3. The issue of Gepid survival was discussed in connection with the 250 skeletal remains uncovered at the Ároktő, Csík-gát site (5th to 9th centuries). The authors hypothesized that one part of the Ároktő population survived from the 5th century to the early Avar period (6th century). In their work, they describe the individuals with deformed skulls and skulls bearing the signs of unintentional cranial modification, probably caused by a tight-fitting hat.[18] According to further investigations,[19] t they were of Europid ancestry, predominantly Cromagnoid types (crC+mongolid), whereas the individual in feature 44 has Mongolid ancestry (Sinid type: long – dolichocranicand low brain-skull-chamaecranic). The remains from feature 7/a show periostitis and osteolytic alterations on the 5th lumbar vertebrae and on the sacrum, indicating possible beginning tuberculotic alterations.[20]

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[12] Varga et al. 2003.

[13] Farkas – Lipták 1971.

[14] Hajdu – Bernert 2007.

[15] Marcsik – Hegyi 2011.

[16] Gál 2007.

[17] Miladinovič-Radmilovič 2011.

[18] Kővári – Szathmáry 2003; Molnár et al. 2014; Molnár et al. 2014a discuss skulls from Ároktő as well.

[19] Taxonomic definitions and the examination of pathological deformations was done by Antónia Marcsik as part of the Széchenyi grant 05/81

[20] A short thesis was written earlier about the Ároktő population: Zsigó, Krisztina: *Az ároktői (Csík-gát) temetőben feltárt hun-germán és késő avar kori népesség összehasonlító vizsgálata* [A comparative analysis of the Hun–Germanic and late Avar period populations in the light of the Ároktő (Csík-gát) cemetery remains]. Thesis, Department of Evolutionary Zoology and Human Biology, University of Debrecen 2003.

The number of skeletal remains discussed in the published studies (together with the ratios of adults vs. children and males vs. females) is given in Table 1.

Table 2 summarizes the data from theses and a final grant report.[21]

4. The skeletal material of some sites is very fragmented, and/or has been lost or mixed with material from other sites over the years. Such a case is the three Gepid cemeteries in the Szentes area, which yielded many remains. Szentes-Nagyhegy: of the material from the 97 uncovered graves, only the skeletons of 12 individuals were available for examination. The male skulls were measured as medium long (mesocranic) and high (hypsicranic), with a wide forehead (eurymetopic), the face is medium wide (mesoprosopic) or wide (euryenic). The following pathological alterations were found: cribra orbitalia (porotic), fracture on the corpus of the right tibia. Szentes-Kökényzug: the number of the examined skeletal remains is 9, from the 74 uncovered graves. The male skulls are long (dolichocranic), their height is medium to high (metriocranic to akrocranic) and the face is wide (euryprosopic-euryenic). Taxonomically they show Cromagnoid characteristics. The skull from feature 75 is deformed. The third large cemetery is Szentes-Berekhát, the skeletal material of which has not been examined.[22]

The skeletal remains from the Szőreg-Téglagyár site were first discussed in a thesis. The results were corrected later, and only 90 individuals were examined further.[23] Two skulls (features 47 and 75) were artificially deformed. The males had long (dolichocranic) and high (hypsicranic and akrocranic) crania, their forehead and face were wide (eurymetopic and mesoprosopic-mesenic, respectively). The indices of female skulls are the same as those of the male skulls, but their faces cannot be characterized. Taxonomically they represent the Cromagnoid type (crA, crB) and a pronounced Nordoid variant. The majority of the observed pathological alterations are common in ancient populations (degenerative spondylosis, porotic type of cribra orbitalia), moreover, DISH (feature 3, male) and inflammation in the auricular surface (feature 13, female) were found; characters indicative of entesopathia also need to be mentioned. At the Hódmezővásárhely-Kishomok site, of the 107 uncovered graves, the very fragmented skeletons of 44 individuals were available. The ratio of the preserved skulls is low the material mainly consists of fragments and teeth only (18 individuals).[24] The number of children and juveniles is very low (3). The number of adults is 41, 14 male and 9 female, with 21 of unidentifiable sex and age. Male skulls are long (dolichocranic), medium high and high (orthocranic and akrocranic), foreheads are wide (eurymetopic). Male faces and female skulls are not possible to evaluate. In both sexes the Cromagnoid and Nordoid types predominate, and females are also characterized by gracile form with brachymorph tendencies. Other details that

[21] For the metric values of the skeletal remains from the cemeteries of Tiszakarád, Magyarcsanád-Bökény, Szőreg-Téglagyár, Ártánd-Kisfarkasdomb, Ártánd-Nagyfarkasdomb, Hódmezővásárhely-Kishomok, Klárafalva-C, Szentes-Berekhát, Szentes-Kökényzug, Szentes-Nagyhegy, see Szathmáry et al. 2008; for a general processing of the data, see manuscripts (Antónia Marcsik). Additional sites: Csáki, Éva: *V. és VI. századi csontvázanyag embertani vizsgálata* [The anthropological examination of the skeletal material of the 5th and 6th centuries]. Thesis, Department of Anthropology, University of Szeged, 2004; Ártánd-Nagyfarkasdomb, Ártánd-Kisfarkasdomb: Csiszár, László Viktor: *A Biharkeresztes-Ártánd környéki gepida temetők összehasonlító, általános embertani feldolgozása* [A comparative, general anthropological processing of Gepid cemeteries in the vicinity of Biharkeresztes-Ártánd]. Thesis, Department of Anthropology, University of Szeged, 1998. The latter thesis manuscripts have gone through some corrections. Cluj-Banatulni, Iclod, Ludas-Varjú dűlő, Egerlövő, Kisköre-Pap tanya, Mezőkeresztes-Cethalom: Antónia Marcsik's manuscript.

[22] The material of the third cemetery in the vicinity of Szentes, Szentes-Berekhát, was not analyzed for this paper because it is very fragmented and has been mixed up with other materials in storage.

[23] The distribution of sexes and of age groups has been marked in Margit Nagy's paper (Nagy 2005, 123–134).

[24] The skeleton uncovered by Lívia Bende and Gábor Lőrinczy in 2002 in the area of sandpits I-IV, Hódmezővásárhely-Kishomok, and the partial child's skull and very fragmented skeleton from the Kishomok site, received as a gift in 1980, are well preserved.

are important to mention are the pronouncedly robust skulls from features 98 and 64, the slightly Mongoloid nature of the skull from feature 69, and the (primarily morphological) similarity of the skulls from featuress 64 and 68. It is most likely due to the low number of skeletons and their very fragmented nature that pathological alterations are negligible (cut marks in facial bones and some cases of porotic cribra orbitalia are all that can be mentioned).[25]

5. This group includes sites material from which can be described as preserved quantitatively and qualitatively medium well or worse. Ártánd-Kisfarkasdomb: 44 of the uncovered 50 graves contained skeletal remains, of which 18 skulls and postcranial skeletons are fairly preserved. The cranium, unearthed in feature 19 is deformed. Taxonomically, in both sexes Cromagnoid-A and -B, and Nordoid types predominate, and one female skeleton demonstrates brachymorphic tendencies. Pathological alterations are negligible, with the exception of the female skeleton from feature 35, which shows considerable fusion of the elbow joint. Ártánd-Nagyfarkasdomb: the entire material that consists of 7 skulls, are less suitable for taxonomic analysis. In both sexes the Cromagnoid-A, Cromagnoid-Nordoid, and Nordoid types predominate, however, one female skeleton is of Gracile Mediterranean type. The number of pathological alterations (mild cases of degenerative spondylosis) are very few. The skull from feature 35 is deformed, whereas the one from feature 43 is indicative of surgical trephination. The skeletal material from the Tiszakarád site is poorly preserved, of the 50 cases, only 6 skulls can be more or less measured. Taxonomically, the Nordoid type predominates, and two skulls have especially long cranial length (features 14 and 30). Their pathological alterations are exclusively mild, with only one or two cases of osteoarthrosis and cribrotic types of cribra orbitalia. In the Magyarcsanád-Bökény series the skeletons of 17 individuals were examined (including a skull with no feature number). The skulls were hardly measurable, and two or three of them showed dolichomorphic tendencies. The Cluj-Banatulni[26] series are highly fragmented and only partially preserved – in several cases only a small number of bones (or bone fragments) were measurable. The taxonomic definition of only one skull was possible, it is of Europid ancestry and dolichocranic. From a pathological perspective, the femur fracture of an 8–10-year-old child and the very serious but healed osteomyelitis of the remains in feature 61 are significant.[27]

6. The skeletal material of some series is better preserved. The Klárafalva-C cemetery sample consists of 3 male and 3 female skulls (the postcranial skeletons were lost). One female skull is of juvenile. Their measurements show them to be dolichocranic and mesocranic. Taxonomically, one female has gracile Mediterranean, two males reveal Cromagnoid characteristics. From the pathological perspective, mild degree degenerative spondylitis can be mentioned, and, in a female skull, the cribrotic-trabecular form of porotic hyperostosis. The Iclod site contains a fragmented and incomplete mature male skeleton with a pronouncedlydolichocranic skull. From the Egerlövő-Homokpart site, a mature female skull is strongly deformed and specifically of the Mongolid type.[28]

[25] For data on the sex and age distribution of the material of 79 skeletons from Hódmezővásárhely-Kishomok see Bóna and Nagy 2002, 41–75; for data on the cemetery population (sex and age distribution, body height, taxonomy, and skull deformation), see Nagy 2004, 169–173. The author used the anthropological data on the basis of István Kiszely's description.

[26] Of the authors, Antónia Marcsik carried out an anthropological investigation in 2002-ben as part of a Széchenyi grant (05/81) in the Historical Museum in Cluj-Napoca (Muzeul National de Istorie a Transilvaniei). The material of the two Gepid sites (Cluj-Banatulni and Iclod) was made available for investigation by Tudor Sălăgean (head of archeology department at the time).

[27] Both femurs and the right tibia are very thickened.

[28] The investigation of the deformed skull (grave 1) from the Egerlövő-Homokpart site was carried out under grant

The skeletal remains of the 4individual uncovered at the Ludas-Varjú-dűlő site are in rather poor and fragmented state. A female skull shows Mongolid characteristics in addition to Europid ones, and one male skeleton bears signs of degenerative spondylitis. From the material of the 9 Gepid graves of the Kisköre-Pap tanya site, 6 skeletal remains were examined. From a taxonomic perspective, the skulls from features 41 and 43 show characteristics of the Cromagnoid type with some Mongolidmorphological traits. Pathological alterations are visible in the metatarsal in feature 41 in form of healed osteomyelitis.[29] In addition to the two adult skeletons (1 male, 1 female) at the Mezőkeresztes-Cethalom[30] site, 8 infant skeletons were also uncovered here. The female skeleton (feature 3) is strongly deformed, next to it two subadult skeletons were found. The male skeleton (feature 24) was found away from the others.[31] This skeleton is extremely robust, archeomorphic (protruding glabella and external occipital protuberance with superior nuchal line, as well as a forehead inclined back).

Summarizing works

In his book, Pál Lipták discusses a few cases from the Gepid period, and, accepting Altheim and Haussing's views,[32] according to which the habit of skull deformation goes back to the Alans, who migrated to the Central Danube Basin together with the Huns.[33] According to Lajos Bartucz, the Gepids adopted the habit of skull deformation from the Huns.[34] Erzsébet Fóthi provided a comprehensive description of the anthropological characteristics of the population of the Central Danube Basin from Roman times to the 9^{th} century, so her study includes the Hun/Germanic period as well.[35] Pathological alterations in Gepids have also been described.[36] Kinga Éry addressed the issue of average statures in populations of various archeological periods. In the 5^{th}–6^{th} century Germanic period (including some Gepid series), the average stature for men was 170.06 cm, for women 161.23 cm.[37] Szathmáry and his colleagues carried out biometric examinations with regard to the 1100-year-long history of the Great Hungarian Plain from the perspective of the survival of populations. In their results they mention, regarding the Germanic era, that the invasions of the time and the settling of the early Avars considerably (in 67–70%) changed the craniological features of the population of the Great Hungarian Plain. Their variants can be traced to the 10th–11th centuries to the extent of 10–6 and 8–9%.[38]

Michael Finnegan and Antónia Marcsik attempted to evaluate the biological distance between the populations of various archeological periods based on the frequency data of non-metric

05/81, with Emese Lovász's permission. Altogether 52 graves were uncovered at this site (Lovász 1991, 57), however, the anthropological examination of these graves has not been carried out. Grave 1 is from the 5^{th} century (Lovász 1991, 61).

[29] The examination of the material from the Ludas-Varjú dűlő and Kisköre-Pap tanya sites was carried out under grant 05/81, with the approval of County Museum Director Tivadar Petercsák.

[30] The processing of the Mezőkeresztes-Cethalom site was possible under Széchenyi grant 05/81, with Mária Wolf's permission.

[31] Wolf and Simonyi 1997.

[32] Lipták 1983.

[33] The Alans may have arrived with the Sarmatians and brought the habit of deformation with them. Several studies dealing with the Sarmatian period (Hajdu and Bernert 2007; Marcsik 2011; Paja 2003) deformed skulls, but it may also have been the case that the Sarmatians themselves brought the habit of skull deformation with them.

[34]Bartucz 1936.

[35]Fóthi 2000.

[36] Marcsik and Szathmáry 2002.

[34] Bartucz 1936.

[35] Fóthi 2000.

[36] Marcsik and Szathmáry 2002.

[37] Éry 1998.

[38] Szathmáry et al. 2008

anatomical traits.[39] In his paper Gábor Holló examined the anatomical-biometric differentiation of the two regions of the skull (the facial vs. brain skull) in the 11th century long history of the Great Hungarian Plain. He concluded that there are significant differences between the two consecutive periods (the Gepid period and the early Avar period) in the main components of the cranium.[40]

Summarizing results

Based on the published studies, manuscripts and grant reports, we can say the following regarding the population of the Gepid period.[41] The qualitative and quantitative values of the skeletal material of the various series are extremely low. These can be explained by taphonomic reasons, on the one hand, although we have to mention that the uncovering of several cemeteries happened a very long time ago, and the anthropological material was not preserved or stored properly, leading to the loss of some of it. Further confounding factors are the mixing with other materials in such a way that only a part of it remained (e.g. Szőreg-Téglagyár, Hódmezővásárhely-Kishomok, the sites of the vicinity of Szentes).

The demographic picture of the populations is fairly different, and the ratios of the sexes and of adults vs. children do not agree with the expectations (see Tables 1 and 2). These disproportions may be due to the fact that the cemeteries are not fully uncovered, or, as has been mentioned above, the skeletal material has been partly lost. According to the published sources, the 405 skeletons are not representative, the number of accidentally discovered single graves is very high, and, at the same time, there are many artificially deformed skulls, on the basis of which it is impossible to draw a general picture about the population. The same is true of the 356 skeletons described only in manuscripts.

Most papers provide detailed descriptions of deformed skulls, while the general metric analysis of non-deformed individuals is included in relatively few of the studies. Even though based on the metric values some differences emerge between the individuals of the various sites, in general the long, narrow, and high neurocranium and narrow to medium viscerocranium seem to be characteristic. The estimated stature is 170 cm for men and 160 cm for women. Almost all skeletons belong to the Europid great group (mostly Nordoid and Cromagnoid, to a smaller extent gracile Mediterraneans), whoever, the Mongolid component plays a part in the material of several cemeteries.[42] In the material of Kiszombor-B cemetery Lajos Bartucz mentioned the Mongolid and Paleoasian types in addition to the Nordic, Mediterranean, and East European types. János Gáspár found mostly skeletons of the Nordoid type and to a lesser extent of the Ural-Altaic type in the material from the Hódmezővásárhely-Gorzsa, Kiss P. tanya site. The Mongolid (Mongoloid) component is likely connected to Hun ethnicity, a suggestion put forward by the two authors mentioned above as well. The survival of the Sarmatians and their influence on the Gepid period also need to be mentioned,[43] however, the Mongolid component occurs only sporadically among the Sarmatians,[44] and it is unlikely that the few cases bearing Mongolid features would have affected the Gepid population greatly. This supposition is also supported by the fact that the material of the

[39] Finnegan and Marcsik 1989; Finnegan and Marcsik 1989a; Finnegan and Just 2000. Unfortunately, the authors discuss only two Gepid materials in their work: Kiszombor-B and Szőreg-Téglagyár

[40] Holló 2013.

[41] A shortened version of the report on the Gepids is also given in the grant report 05/81

[42] Kál-Legelő III: two skulls are Mongolid and Mongoloid; Ároktő-Csík-gát, Ludas-Varjú dűlő, Egerlövő: one skull in each site is Mongolid; Kisköre-Pap tanya: two skulls are Mongolid.

[43] On the right bank of the Tisza river there are sites where Sarmatian and Gepid skeletal remains were found together, suggesting that in this region Sarmatians may have lived under Gepid dominance (Vörös 1989, 54).

[44] In the Sarmatian population the Europid (Pamir) type predominates

Ártánd-Nagyfarkas, and Ártánd-Kisfarkas sites,[45] dated to an earlier Gepid phase, is completely of Europid character. The Mongoloid influence is also detectable on the two skulls of Kisköre-Pap tanya site. The individuals in three features (42, 43, and 24) were buried along with early Avar period finds,[46] and with this population we can presuppose a Hun or perhaps and early Avar period Mongoloid influence.

Pathological alterations are infrequent and, with the exception of one or two cases, not serious. Traumatic alterations are seldom found. Traces of the diseases of joints (osteoarthritis), even of degenerative attrition of the cartilage (degenerative arthritis or spondylosis), are extremely rare, and bone alterations suggesting heavy and strenuous physical labor (entesopathic symptoms) are infrequent. Traces of skeletal tuberculosis was discovered in only one case (Ároktő), whereas traces of other infectious diseases were not. Porotic forms localized on bones (cribra orbitalia/cranii) are typical alterations of metabolic disorders and were found with average frequency and in mild form. A skull (Kiszombor-B) with signs of tumor manifested on the bone found was a unique case.[47] Osteomyelitis occurred on the skeletal remains uncovered in Iclod, Kál-Legelő, and Kisköre-Pap tanya. The skull of the individual in grave 43, Ártánd-Nagyfarkasdomb, the sign of surgical trephination (on the left side, at the upper region of the occipital bone and the lower region of the parietal bone, with a diameter of 5 cm). The margin of the cut is smooth, the three layers of the skull cannot be seen, and the patient survived the procedure.[48] Based on the above-mentioned facts we can conclude that the types of occurring paleopathological alterations are few, their frequency is low, at least on the basis of the examination of the available skeletal material.

In terms of a comparative analysis of different series, Viktor Csiszár's thesis is significant.[49] The author carried out a comparative analysis of Gepid cemeteries in the vicinity of Biharkeresztes. Of course, due to the small number of series, the significance relations have to be treated with caution, however, because of the robust differences between the series, some conclusions can be safely drawn. Based on the results of hierarchic cluster analysis (carried out with SYN-TAX 5.02), we can state that a connection between the male populations of Ártánd-Kisfarkasdomb and Biharkeresztes-Toldi útfél is possible to show, whereas that of Nagyfarkas domb is different from the other two. Regarding a comparison between the female populations, based on the calculated distance matrix, the connection between Ártánd-Kisfarkasdomb and Biharkeresztes-Lencsésdomb is fairly close. When comparing the averages of the series, it became apparent that the individuals of the Kisfarkasdomb and Lencsésdomb cemeteries were closely connected, and less closely to those in Nagyfarkas- domb.

According to archeological observations, the survival of some Gepid populations in the Tisza area (Egerlövő, Kisköre, Hódmezővásárhely-Kishomok, and Szőreg-téglagyár) in the early Avar period can be presumed,[50] however, at this time there is no general anthropological data available to support this claim. The Egerlövő material has not been fully processed, the Kisköre material has very few individuals, and the skeletal remains of the 6 individuals from the Avar period graves at the Hódmezővásárhely-Kishomok site are extremely fragmented and, thus, are unsuitable for general anthropological analysis. Relying on István Kiszely's description, in her work Margit Nagy[51]

[45] Istvánovits et al. 1996; Mesterházy 1989; Mesterházy 2009.
[46] Dobos 2012, 99.
[47] Marcsik et al. 2002.
[48] The shortened version of the metric, taxonomical and pathological analysis was included in the grant report 05/81.
[49] Csiszár, László Viktor: *A Biharkeresztes-Ártánd környéki gepida temetők összehasonlító, általános embertani feldolgozása* [A comparative and general anthropological analysis of Gepid cemeteries in the vicinity of Biharkeresztes-Ártánd]. Thesis, Department of Anthropology, University of Szeged, 1998
[50] Nagy 2004, 174. Nagy 2005, 197.
[51] Nagy 2004, 171.

mentions that the Avar period individuals uncovered at this site are unanalyzable. In addition to the Gepid graves, early Avar period graves were also uncovered at the Szőreg-Téglagyár site. On the basis of their anthropological examination[52] the only thing that can be stated with confidence is that a new population settled here in the early Avar period, whose taxonomic composition is greatly different from that of the Gepids'. In type analysis and further morphological characteristics they show similarities with the early Avar period population of Makó-Mikócsa halom[53] (robust Mongolid, Europo-Mongolid types, and surprisingly archaic; in the area of occipital bone, the arch and protrusion of the superior nuchal line, the very low position of the external occipital protuberance, and a sagittal protrusion in the region of the frontal bone). From the perspective of archaic features, the skull from feature 55 is especially noteworthy (with a protruding glabella region and a forehead greatly inclining back). On the basis of the morphological alterations of the occipital region, the individuals in features107, 110, and 122 can, without doubt, be assigned to the same family.

Taking into account the anthropological heterogeneity of the Gepids, based on the published studies and unpublished manuscripts, it is more correct to talk about the population of the Gepid period (rather than "the Gepid population"). In our view, the issues of heterogeneity and of the Avar period survival and continuity of the Gepid population would be best supported by the biochemical molecular analysis of well-preserved skeletal remains from well represented cemeteries.

Conclusion

In the present paper the authors provide an approximate picture of the biological reconstruction of the Gepid population on the basis of published studies and unpublished manuscripts. According to metric data, the cranium is usually long (dolichocranic) and medium high (orthocranic) or high (hypsicranic), the facial skull medium long (mesoprosopic) to long (leptoprosopic), in some cases wide (euryprosopic). According to taxonomic analysis, almost all skeletons belong to the Europid great group – Nordoid, Cromagnoid (crA, crB), gracil Mediterranean – however, in the material of several cemeteries the Mongolid (Mongoloid) component is also present, presumably due to the Hun ethnic group. With the exception of one or two serious cases, pathological alterations are insignificant.

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[52] Marcsik manuscript.

[53] Marcsik: Makó-Mikócsa halom kora avar kori népessége [The Avar period population of Makó-Mikócsa halom]. Manuscript. In OTKA grant: "Human landscape interactions in the Maros valley during the first half of the Avar period based on comparative interdisciplinary study of the archeology" (Supervisor: András Gulyás).

Table 1: Distribution of the sexes and adults vs. infants (published data)

Sites	Subadults	Adults			Total
		♂	♀	?	
Hódmezővásárhely-Gorzsa, Kiss P. tanya (Gáspár 1931)	10	15	5	-	30
Kiszombor-B (Bartucz 1936)	6	38	18	1	63
Tápé-Széntéglaégető (Farkas – Lipták 1971)	-	-	1	-	1
Biharkeresztes, Ártánd-Lencsésdomb (Lipták-Marcsik 1977)	1	4	5	-	10
Biharkeresztes-Toldiútfél (Lipták – Marcsik 1977)	1	3	3		7
Endrőd-Szujókereszt (Pap 1983)	-	1	-	.	1
Gyula-Fövenyes (Farkas et al. 1991)	-	1	-	-	1
Hratkovci-Vranj (Sirmium) (Zoffmann 1992) (deformed skull)	-	-	1	-	1
Hrtkovci-Vranj (Sirmium) (Zoffmann 1998) (deformed skull)	-	1	-	-	1
Viminacium (Mikič 1999)	16	46	27	5	94
Szolnok-Szanda (Varga et al. 2003)	33	41	17	7	98
Ároktő-Csík gát (Kővári – Szathmáry 2003; Molnár et al. 2014a-b	4	7	9	-	20
Rákóczfalva-Bivaly tó (Hajdu – Bernert 2007)	3	4	1	-	8
Alba Iulia-Proprietatea Staicu (Gál 2007)	-	-	-	-	14
Kál-Legelő (Marcsik – Hegyi 2011)	9	7	5	1	22
Sirmium (Miladinovič-Radmilovič 2011) (all Germans)	18	9	4	3	34
Total	101	177	96	17	391
	101	177	96	17	391+14
	405				

Table 2: Distribution of the sexes and adults vs. infants after corrections (based on manuscripts)

Site	Subadults	Adult			Total
		♂	♀	?	
Tiszakarád	9	15	26	-	50
Magyarcsanád-Bökény	6	7	4	-	17
Szőreg-Téglagyár	26	31	33	-	90
Klárafalva-C	-	3	3	-	6
Hódmezővásárhely-Kishomok	4	15	9	13	41
Szentes-Nagyhegy	1	7	3	1	12
Szentes-Kökényzug	-	7	1	1	9
Ártánd-Nagyfarkasdomb	18	17	14	2	51
Ártánd-Kisfarkasdomb	11	16	14	3	44
Domaszék	-	2	1	-	3
Cluj-Banatulni	5	2	4	-	11
Iclod	-	1	-	-	1
Egerlövő	-	1	-	-	1
Kisköre-Pap tanya	2	3	1	-	6
Ludas-Varjú dűlő	2	1	1	-	4
Mezőkeresztes-Cethalom	8	1	1	-	10
Total	92	129	115	20	356

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SPORTS MEDICINE AND SPORTS TRAUMATOLOGY ASPECTS OF ARCHERY. ANATOMICAL DATA FOR THE BETTER UNDERSTANDING OF THE ARCHERY-RELATED SKELETAL CHANGES

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Keywords: Archery, anatomy, sports medicine, sports traumatology, activity-induced skeletal changes

Abstract

In this paper, we give a review of the archery-related sports medicine and sports traumatology studies. Archery is a static, non-contact sport requiring the endurance and strength of the upper body. The shooting process is a complex movement that involves a wide scale of muscles. EMG and kinematic analyses highlighted the importance of the shoulder and elbow regions and the differences in the muscle activation strategies of elite and beginner archers. Training is essential in order to avoid the exhaustion-related traumas and decrease in accuracy. Although the risk of injuries is relatively low, the high amount of load still presents a major factor for developing traumas. In archery, the acute type alterations are rare, but the overuse or chronic micro- and macrotraumas are common, especially in the shoulder and elbow regions. The anatomical knowledge on archery gives us the required information to properly evaluate the activity-related skeletal changes in samples from the 10th-century AD cemetery of Sárrétudvari-Hízóföld. It is clear that, for future investigations, a complex methodology is necessary to analyze the possible archery-related skeletal changes.

Introduction

Historical[1] and archaeological[2] sources clearly state that Magyars in the 9th and 10th centuries had strong traditions considering archery, in particular, mounted archery. Nowadays, this

[1] E.g. the importance of bow and archery were described by the byzantian Emperor Leo VI the Wise, or Regino of Prum (HKÍF 105, 198).
[2] E.g. Kovács 1986, Révész 1996.

tradition lives its renaissance, since the so-called Hungarian historical archery is a dynamically developing sport and social free-time activity.[3] In recent years, the number of the Hungarian champions and world records started to increase, and the 9th–11th-century AD Magyar type bow[4] has become one of the Hungaricums.[5] On the other hand, a duality can be noticed concerning the traditional archery in Hungary: the aim is mostly to reproduce and to represent the style of the early Hungarians, but the base is still the sports archery technique that is developed by the English traditions. Furthermore, the archery equipment used to differ from the characteristics of the 10th-century AD bows, quivers, and arrows. Although great tasks have been accomplished to reach the scientific approach,[6] the results of the competent studies are still not well-known among the wider public. The main problem is the limitation of the sources (historical and archaeological), which makes the well-planned experimental archaeology studies[7] and the interdisciplinary research projects more important.

In relation to the second course-line of the above-mentioned studies, we have started to carry out archaeological-anthropological investigation recently and published our first results about the activity-related skeletal changes of the possible archers from the Sárrétudvari-Hízóföld 10th-century AD cemetery.[8] According to our preliminary results, the complex bioarchaeological analysis gives us the utmost help to identify the archers inside the cemeteries, to get more information about the link between burial rituals and daily activities, and to describe the different archery techniques. Nevertheless, certain questions and problems have lighted that the proper evaluation requires knowledge not only on the archaeological and anthropological data but on the detailed sports medicine and sports traumatology background, as well.

In this paper, we would like to give a review of the archery-anatomy-related studies for the better understanding of our anthropological results. First, we describe the characterization of archery and the shooting process. After that we summarise the archery-related anatomy and injuries, and finally, we compare the data with our own skeletal results.

The description of archery and the shooting process

The reputation of archery have highly increased in recent years, as it is a free-time and recreational activity fitting for all age-categories from children to elderly.[9] Since modern foot-archery belongs to the Olympic Games,[10] different sports medicine, sports traumatology, and biomechanics studies focus on this type of archery. However, the investigation of the traditional styles is a rare phenomenon.[11] As there is no published data about the analysis of Hungarian traditional foot-archers or mounted archers, we summarise the anatomical aspects of archery based on the modern-archery-related international results.

Archery is described as a comparatively static sport, which requires strength and endurance of the trunk, the shoulder girdle, and the arms.[12] The archery skill is defined as shooting the arrow

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[3] Bíró–Bencsik 2014.

[4] Bencsik–Borbély 2014.

[5] http://www.hungarikum.hu/hu/ix-xi-sz%C3%A1zadi-magyar-%C3%ADj

[6] In the form of literature (e.g. Bíró–Bencsik 2014, Petkes–Sudár 2015) and authentic groups (e.g. Magyar Történeti Íjász Társaság) as well.

[7] Igaz 2010, Bencsik 2012, Igaz 2014.

[8] E.g. Tihanyi et al. 2015, Tihanyi et al. 2016.

[9] Gianikellis et al. 2000.

[10] Singh–Lee 2016, You et al. 2016.

[11] See in Ariffin et al. 2018.

[12] Mann–Litke 1989, Erthan et al. 2003, Kosar–Demirel 2004, Erthan et al. 2008.

into the target with accuracy,[13] which requires 3–4 hours practicing a day, 5 times per week, and should be started at least at the age of 12–14.[14]

The shooting process is divided into 3[15], 6[16] or – with the preparation phases – 8[17] steps. In particular, it contains the stance, drawing, and aiming steps,[18] or the bow hold, drawing, full draw, aiming, release, and follow-through steps.[19] The archer holds the bow in one hand (*i.e.*, bow arm) and pushes it with an extended arm statically in the direction of the target, while the other hand (*i.e.*, drawing arm) dynamically pulls the bowstring toward the opposite direction.[20] Squadrone and Rodano distinguished two different drawing styles: lifting and holding the bow in a nearly straight hand then pulling with the drawing arm, or lifting both arms and – at the same time – moving them in the opposite directions.[21] The release phase is essential: it must be well-balanced and highly reproducible to achieve prominent results.[22] Moreover, the proper physical state of the archer is very important in order to hold the pulling force of the bow, which is influenced by the position of the arms and the trunk.[23]

Anatomical characterization of archery

In the shooting position, the feet of the archer straddle the shooting line at 90° to the target. Ideally, the arms are held at 90°[24] or greater abduction until the end of the shooting process and the shoulders are in a flexion position, allowing the fingers to grab the bowstring.[25] The complex work of the trunk, shoulder, arm, forearm, and hand muscles is needed to successfully take this position (Fig. 1).[26]

Regarding the bow arm, the *musculus deltoideus* elevates the bow, whereas the *m. triceps brachii* is responsible for the extension of the arm. The *m. serratus anterior* pulls the scapula forward, and consequently the arm to the direction of the target. The *m. latissimus dorsi* is responsible for keeping the shoulders on the proper level. The *m. teres major*, *m. teres minor*, and *m. subscapularis* rotate the arm, preventing the string touch injuries. The *m. pectoralis major* and *m. pectoralis minor* bring the shoulder girdle more forward to take the shooting position.

Concerning the drawing arm, the *m. biceps brachii* and *m. pectoralis major* bring the hand forward to grab the bowstring with the fingers. The *m. deltoideus* and *m. supraspinatus* elevate the arm onto a horizontal level. Depending on the technique, the flexor muscles of the fingers grab the bowstring. The pulling requires complex muscle work. The *m. trapezius*, *m. romboideus minor*, and *m. romboideus major* move the scapula toward the spine, the *m. deltoideus* (posterior) and *m. infraspinatus* bring the arm backward, whereas *m. deltoideus* (medialis) keeps the arm on a horizontal position (or above). All the listed muscles are involved in the shooting process, but unequally.

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[13] Leroyer et al. 1993.
[14] Discussed by Sezer 2017.
[15] Leroyer et al. 1993, McKinney–McKinney 1997.
[16] Nishizono et al. 1989.
[17] Taha et al. 2017.
[18] Leroyer et al. 1993, McKinney–McKinney 1997.
[19] Nishizono et al. 1989.
[20] Leroyer et al. 1993.
[21] Squadrone–Rodano 1995.
[22] Nishizono et al. 1989, Horsak et al. 2009, Simsek–Ertan 2014.
[23] Ahmad et al. 2014.
[24] Lin et al. 2010.
[25] Pappas et al. 1985.
[26] Axford 1995, Soylu et al. 2006, Ertan et al. 2008, Miltényi 2008, Reddy 2015.

Numerous studies focused on the analysis of the link between the muscle activation strategies and the efficiency of the archers, using EMG and kinematic techniques.[27] Nishizono *et al.* drew two main conclusions concerning the anatomy of archery. Elite archers showed a higher activity of the back and shoulder muscles than of the arm muscles, and the left and right sides were loaded symmetrically.[28] The beginners showed a higher activity of the arm muscles and asymmetry between the sides.[29] The first strategy has two main advantages:[30] fatigue can be delayed,[31]and the lateral deflection of the bowstring during the releasing phase is minimised; therefore, the shoot will be more accurate.[32] Squadrone and Rodano found that the experienced archers positioned their shoulders almost perfectly into the sagittal plane, the *m. biceps brachii* had lower activation during the shots, and the *m. latissimus dorsi* worked symmetrically between the sides. Furthermore, the bow arm of the less experienced archers showed a deflection, the activation of the *m. biceps brachii* was systematically higher, and the *m. latissimus dorsi* was loaded asymmetrically.[33] Kolayiş and Ertan concluded that the shoulder girdle has the most important role – in particular, *m. trapezius* –, which works symmetrically.[34] Reddy measured the activation of 6 muscles, namely *m. deltoideus (anterior, medialis, posterior)*, *m. trapezius*, *m. biceps brachii*, *m. triceps brachii*, *m. pectoralis major*, and *m. latissimus dorsi*.[35] The *m. deltoideus* and *m. infraspinatus* had the highest activation level among the analysed muscles. The work of *m. deltoideus* is essential for the stability of the arm and the forearm. The higher load of the rotator cuff muscles leads to a faster exhaustion and increases the risk of injuries.[36]

Many studies focusing on the investigation of the forearm and hand muscles activation patterns suggested that both the flexor and the extensor muscles of the fingers take part in the releasing phase (*i.e.*, simultaneous relaxation and contraction) and the position of the *a. metacarpophalangealis* and *a. interphalangealis* determines the result of the shooting.[37] Through historic and prehistoric times, many gripping techniques were in use. Among the five main types, the thumb (Fig. 2) and the three-finger grips (Fig. 3) were the most widespread.[38] Clarys *et al.* found different muscle activation profiles regarding the indoor (25 m) and outdoor (50 m) distance shots.[39] The results of their comparative analysis between four string grip forms (*i.e.*, three-finger grip, two-finger grip, thumb grip, and reversed grip) support the economic advantage of the thumb grip technique.[40] They also found differences between elite and beginner archers that can be explained by the ability to highly reproduce the same movements.[41]

In connection with the string grip techniques (three-finger and two-finger grips), Simsek and Ertan concluded the advantages of the three-finger grip, as in this technique, lateral deflection do not occur.[42]

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27 Discussed by Ertan et al. 2008.
28 Nishizono et al. 1984.
29 Nishizono et al. 1984.
30 Ertan et al. 2008.
31 Açikada et al. 2004.
32 McKinney–McKinney 1997.
33 Squadrone–Rodano1995.
34 Kolayiş–Ertan 2016.
35 Reddy 2015.
36 Reddy 2015.
37 Martin et al. 1990, Ertan et al. 2003, Soylu et al. 2006, Horsak et al. 2009, Taha et al. 2017, Simsek et al. 2018.
38 Schmidt 2015.
39 Clarys et al. 1990.
40 Clarys et al. 1990.
41 Clarys et al. 1990.
42 Simsek–Ertan 2014.

It is clear that the muscle activation profile is variable; the complex work of multiple muscle groups determines the result of the shoot.[43] Practicing is essential for archers to train their muscle strength, endurance, and motor-control, and consequently to create a quasi-static equilibrium of the musculoskeletal system.[44] It helps to delay or avoid the fatigue-effect-related changes in the movement,[45] which are one of the main risk factors for injuries.[46]

The archery-related injuries

Sports have unique injury patterns depending on the dominant stress factors.[47] Two main types of injuries can be distinguished by the underlying mechanism: acute (or traumatic) – *i.e.*, the result of a well-defined single event – and chronic (or overuse) – that is caused by repetitive microtraumas.[48] Although the static and non-contact nature of archery lowers the risk of injuries,[49] the high amount of load (equivalent to pull more than one tonne on a single practice or competition) still presents a major factor for developing traumas.[50] Nonetheless, only several papers – mostly case studies – were published.[51] Furthermore, the possible conclusion of these papers is usually highly limited because of their retrospective, test-like methods and the lack of real medical examination.[52]

Acute injuries are relatively rare in archery, mostly caused by the material failure of the equipment (*e.g.*, breaking of the bow or arrow during the shot) and technical problems (*e.g.*, hit from the bowstring).[53] Most of the injuries are related to chronic, overused type changes. Their classification is based on their localisation and frequency. Several causative factors were recognised, such as the strength of the bow, the high repeat number of the shots, the lack of muscle strength, and technical problems, as well as the sex, age, and the amount of experience.[54]

Recent studies highlighted that injuries develop in the highest ratio in the shoulder region and in particular, in the drawing arm.[55] According to the report of the World Archery (FITA) Medical Committee, 45–50% of the archers have shoulder injuries,[56] but the distribution is different between countries,[57] and the prevalence is not widely reported.[58]

Shoulder impingement is considered predominant among the alterations.[59] The compression of *m. supraspinatus*, *m. biceps caput longum*, and *bursa subacromialis* leads to a painful inflammatory process.[60] Exhaustion is a major risk factor, since it alters the posture and the movements of the arms, and subsequently causes narrowing of the subacromial space; and therefore, increases the pressure.[61] Archers with shoulder impingement have different EMG and kinematic patterns

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43 TINAZCI 2011, SUWARGANDA et al. 2012, HUMAID 2014.
44 SQUADRONE et al. 1995.
45 SQUADRONE et al. 1995.
46 NIESTROJ et al. 2018.
47 ÅMAN et al. 2016.
48 FULLER et al. 2006.
49 NIESTROJ et al. 2018.
50 LANDERS et al.,1986; NISHIZONO et al., 1989, ERTAN et al. 2003; ERTAN 2006, SINGH-LEE 2016.
51 With detailed research history: NIESTROJ et al. 2018.
52 E.g. in the reports of the archery associations: http://www.qsl.net/gi4fum/page5.html.
53 ERTAN 2006, SINGH-LEE 2016, NIESTROJ et al. 2018.
54 GROVER et al. 2017, NIESTROJ et al. 2018.
55 ERTAN 2006, SINGH-LEE 2016, GROVER et al. 2017, NIESTROJ et al. 2018.
56 http://www.qsl.net/gi4fum/page5.html.
57 MANN-LITKE 1989, CHEN et al. 2005, ERTAN 2006.
58 GROVER et al. 2017.
59 MANN-LITTKE 1989, GROVER et al. 2017.
60 NEER 1983, MANN 1997, LITTKE 2004, KAYNAROGLU et al. 2012.
61 NIESTROJ et al. 2018.

(*e.g.*, scapula elevation angle, extension ratio of the elbow, and the activity of *m. trapezius* and *m. deltoideus*).[62] In other cases, muscle tears, *intraarticular ganglion*, degenerative changes of the *a. acromioclaviculare*,[63] and scapular *dyskinesia* with posterior dislocation have been registered in relation to archery.[64]

Concerning the arm, the elbow is the main localisation of injuries. The repetitive overload of the extensor (bow arm) and flexor (drawing arm) muscles can cause painful inflammation (*i.e.*, medial and/or lateral *epicondylitis*[65]).[66] One of the most important phases of the treatment and prevention is the training of the muscles to resist the physical stress.[67] Further changes of the arm and forearm are the acute injuries caused by the string, and as a unique case, a *hypophosphathasia*-related ulnar fracture has been registered.[68]

The injury of the hand and wrist is a relatively rare phenomenon. Mostly, the string touches and arrow related lacerations[69] of the acute group[70] and the chronic type of de Quervain syndrome (*i.e.*, inflammation changes of the *processus styloideus radii*), tenosynovitis of the extensors, and blisters on the fingers were reported.[71] Chronic alterations of the fingers were barely analysed. In their sonographic study, Kaymak *et al.* noticed hypertrophy of the *m. flexor digitorum profondus*, but its precise etiology requires further investigations.[72]

A few cases of chronic injuries of the neck and back have also been published,[73] such as disc herniation, arthrosis of the *vertebrae cervicales*, and degenerative changes of the thoracic spine.[74]

In addition, thoracic outlet syndrome[75] and bow hunter's syndrome[76] were diagnosed exceptionally on people, who frequently practice archery.

In summary, the archery-related injuries can occur all around the upper body, but mainly on the shoulders and elbows (dominantly at the drawing side), supporting the results of the EMG and kinematic studies. Mostly the soft tissues are affected, and it seems that there is no archery-specific trace of trauma on dry bones.

Conclusions: the anatomical data and the results of the anthropological analysis

In our earlier paper concerning the hypertrophies and entheseal changes of the archer (individuals buried with archery equipment) graves from 10th-century AD cemetery of Sárrétudvari-Hízóföld, we concluded the following regarding the anatomy aspects:

62 SHINOHARA et al. 2014.
63 NIESTROJ et al. 2018.
64 FUKUDA–NEER 1988.
65 In the literature it is named mostly as tennis-elbow or golf-elbow, but in the English regions, the archer-elbow term is used as well (MARSICK 2005).
66 SINGH–LEE 2016, NIESTROJ et al. 2018.
67 AMIN et al. 2015.
68 YAVUZ et al. 2013.
69 SINGH–LEE 2016.
70 A unique metacarpal fracture was published as well (VOGEL–RYAN 2003).
71 ERTAN 2006, SINGH–LEE 2016, NIESTROJ et al. 2018.
72 KAYMAK et al. 2012.
73 ERTAN 2006, SINGH–LEE 2016, NIESTROJ et al. 2018.
74 SINGH–LEE 2016, NIESTROJ et al. 2018.
75 The symptoms are weakness and pain, caused by the compression of the *plexus brachialis*. Among other possibilities, the movements of the drawing phase in archery can be a causative factor. (PARK et al. 2013).
76 Known as the vertebrobasilar syndrome and caused by the mechanic or inflammation (e.g. *spondylosis*, lateral herniation) narrowing of the artery at the level of the 1st and 2nd cervical vertebra (MATSUYAMA et al. 1997, JOST–DAILEY 2015). Turning the neck and the head is a basic movement in archery, but it must be noted that the eponym case (SORENSEN 1978) was possibly not the vertebrobasilar syndrome (JOST–DAILEY 2015).

a) the observed markers are bilateral, but their severity shows slight asymmetry;

b) in the hand and finger regions, differences may occur between the bow arm and the drawing arm.[77]

Aline Thomas summarised the problem:[78] earlier, it was thought that archery asymmetrically loads the body. However, contemporary medical studies proved the two-sided nature of archery. Although many parameters influence the development of symmetrical and asymmetrical changes, the experience is one of the most important factors.[79] Knowing the anatomical data, the dominance of the bilateral markers is not surprising, and it could prove that elite archers were buried in the cemetery of Sárrétudvari-Hízóföld. Nevertheless, further investigation is needed.

Studies focusing on the hand and fingers found differences between the bow arm and the drawing arm.[80] Although the chances are low to analyse and register the changes of the phalanges, it is still the only region, where we can suspect archery-related asymmetrical changes.

The detailed anatomy and traumatology knowledge leads us to the conclusion that the investigation of the entheseal changes alone is not enough to the evaluation of the possible skeletal traces of archery. A complex methodological approach regarding the upper limb and the spine is necessary.

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77 Tihanyi et al. 2015.

78 Thomas 2014.

79 E.g. Nishizono et al. 1984, Squadrone–Rodano 1995, Kolayiş–Ertan 2016.

80 E.g. Kaymak et al. 2012.

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List of figures

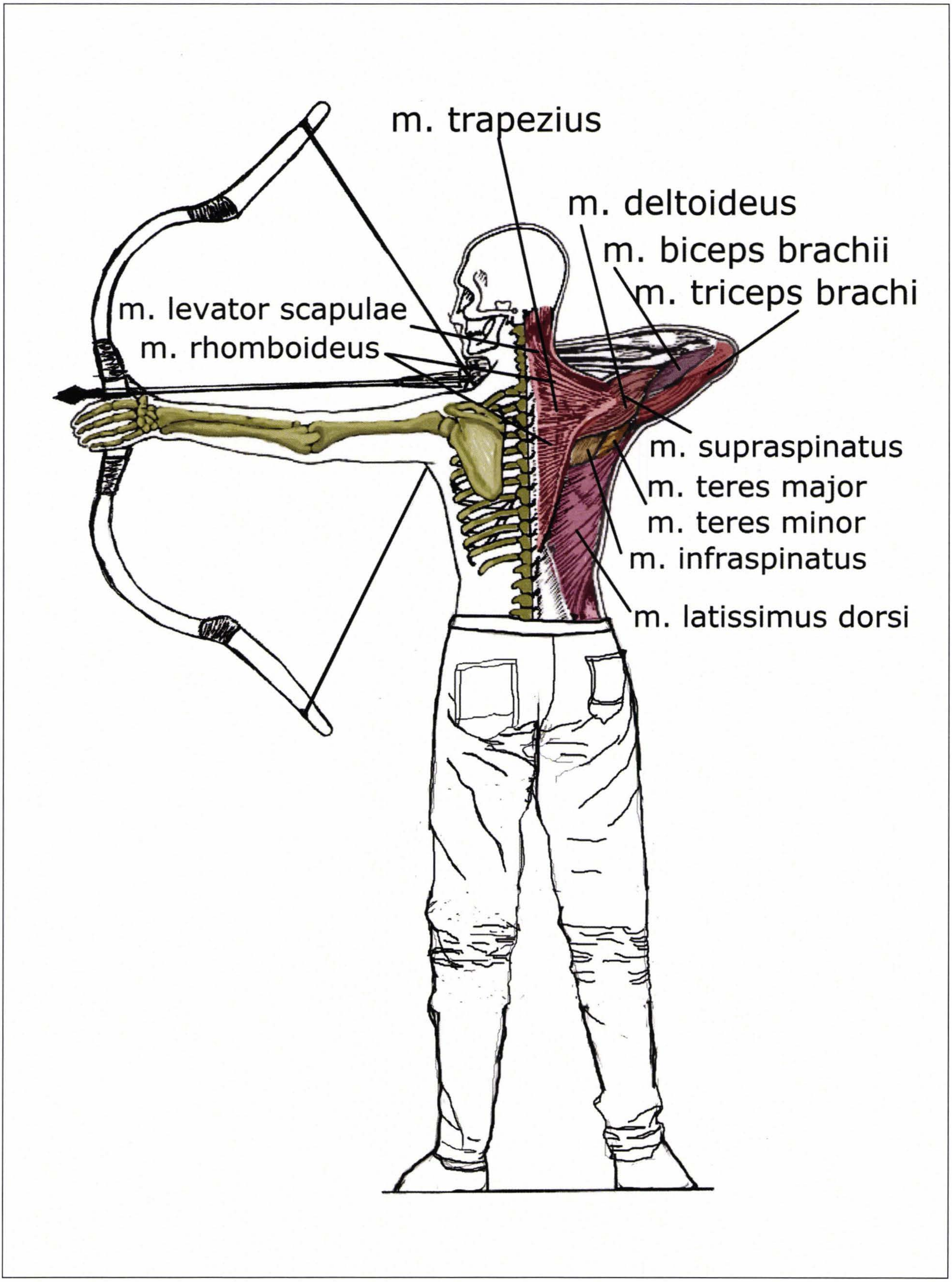
m. trapezius
m. deltoideus
m. biceps brachii
m. triceps brachi
m. levator scapulae
m. rhomboideus
m. supraspinatus
m. teres major
m. teres minor
m. infraspinatus
m. latissimus dorsi

Figure 1

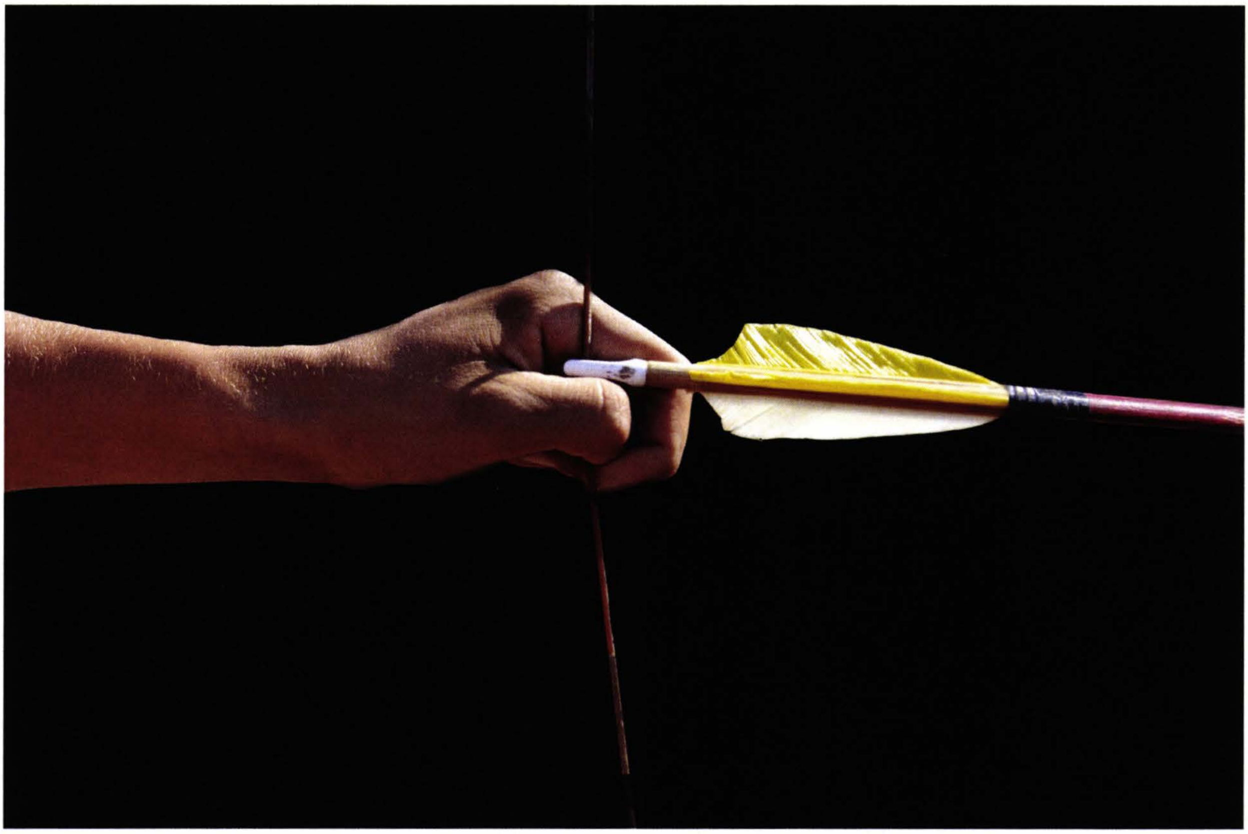

Figure 2

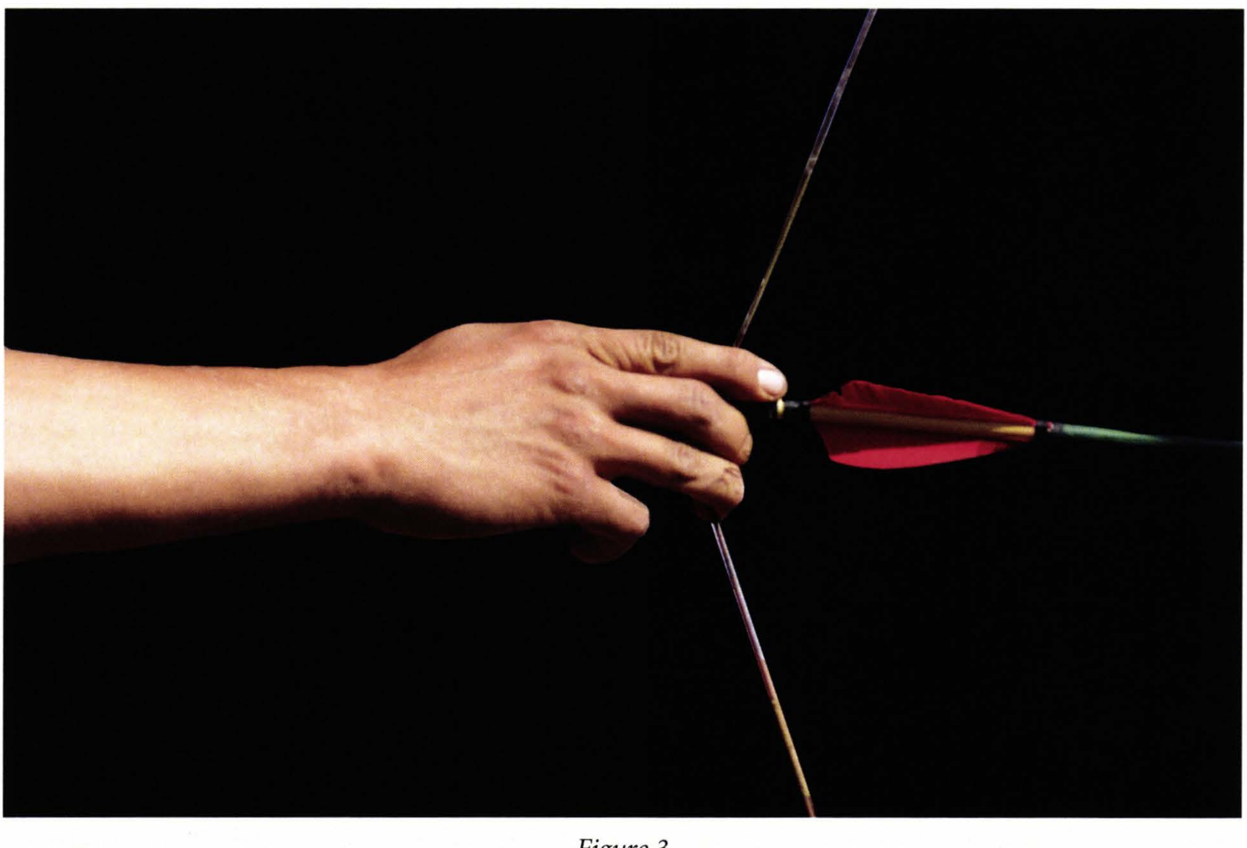

Figure 3

DIFFERENTIATION BETWEEN *MYCOBACTERIUM TUBERCULOSIS* AND THE NON TUBERCULOUS MYCOBACTERIUM GORDONAE VIA HIGH RESOLUTION MASS SPECTROMETRIC TECHNIQUE

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Abstract

Tuberculosis still has one of the highest prevalence among possibly lethal infectious diseases that makes research concerning its pathomechanism and evolution of its infectious agents surpassingly important. The recognition of the presence of the infection in ancient bones requires complex examinations since skeletal tuberculosis occurs only in 2.2 – 4.7% among Mycobacterium tuberculosis infected patients. To complete the macromorphological investigations, a couple of molecular and analytical examinations, such as DNA and lipid biomarker based verification methods, were adapted from the clinical practice to paleopathology since the '90s. Although the usage of ancient DNA (aDNA) has a long tradition as a PCR based diagnosis of tuberculosis in ancient populations, some results are causing concern about its reliability since the aDNA is usually highly fragmented. The aDNA degradations and also the contamination by saprophytic Mycobacterium species can lead to false positive cases. In the clinical and paleopathological practice, the lipid biomarker based verification method also could be applied. Our recent paper will present the preliminary results of amycolic acid based diagnostic protocol, optimized in our laboratory and will possibly provide good resolution power for the examined taxons.

I. Introduction

Tuberculosis (TB) is well known for its devastating effect on population health at the beginning of the 20th century, but has been present as a human pathogen for at least 10,000 years[1]. The relatively still high incidence, the appeared multi drug resistant TB (MDR-TB) strains and co-infection cases (especially with HIV) are highlighting the necessity of extensive TB research[2]. For better understanding of the evolution of the infectious agent the investigations concern the TB epidemiology in past populations. Since the beginning of the '90s the aDNA based methods were primarily used[3]. The

[1] Baker et al., 2015.

[2] WHO, 2018.

[3] Chan et al., 2013; Cooper et al., 2016; Donoghue et al, 1998; Pósa et al., 2012; Spigelman & Lemma, 1993.

IS6110 and IS1081 palindromic sequences were used to verify TB infected cases for decades, but the expanding knowledge pointed to the fact that these sequences can lead to false-positive diagnosis because of the contamination by saprophytic Mycobacteria[4]. Another approach, the lipid biomarker based verification was applied already for a long time[5]. The mycobacterial outer membrane is rich in several type of lipids, especially mycolic acids but variable free lipids can be also detected via analytical techniques[6]. Mycolic acids are long-chain fatty acids containing 70 – 90 carbon atoms. In the case of the members of *Mycobacterium tuberculosis* complex, these mycolic acids can be differentiated into three classes according to their functional group: α-, keto- and methoxymycolates (Fig. 1A.).

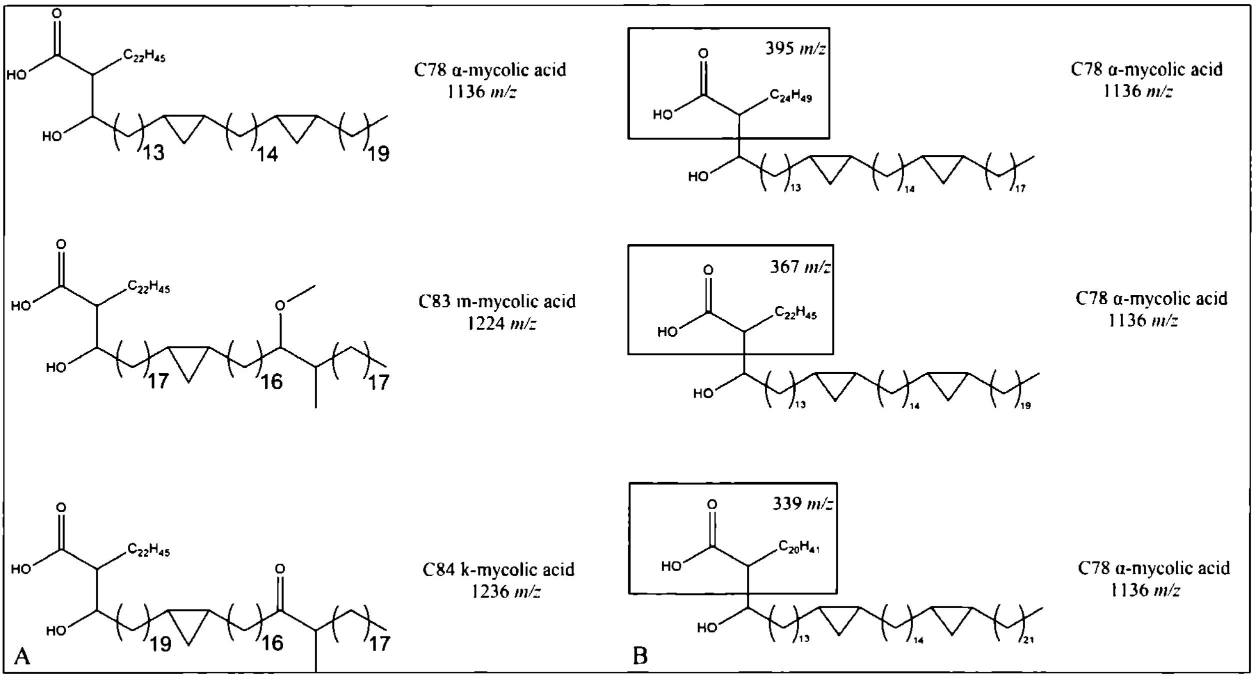

Figure 1.

These lipids provide us the possibility to diagnose tuberculosis infections[7]. The differentiation is based on profiling, and it seems to work well not only on the members of the *Mycobacterium tuberculosis* complex, but alsoon non-tuberculous mycobacteria. Two types of successfully applied mycolic acid based methods could be found in the literature, the high-performance liquid chromatography (HPLC) only[8]. For the first method, the derivatization step is required to make the mycolic acids visible for the UV or fluorescent detectors, however HPLC separation is used in both mentioned techniques. In our work we chose to follow the MS based method without separation and derivatization to improve the throughput of this investigation.

I.1. *Mycobacterium tuberculosis* complex

The *Mycobacterium tuberculosis* complex includes pathogenic *Mycobacterium* species, which can cause tuberculosis among humans and animals[9]. Based on the recent knowledge and the detailed DNA based examinations, more and more species are described and taxonomically characterized

[4] Müller et al., 2016.
[5] Donoghue et al., 1998.
[6] Minnikin et al., 2015.
[7] Butler & Gutherz, 2001; Minnikin et al., 1993;Shui et al., 2011; Song et al., 2009.
[8] Butler & Gutherz, 2001; Minnikin et al., 1993; Hershkovitz et al., 2008) andthe mass spectrometry (MS) coupled HPLCmethods (Song et al., 2009; Shui et al., 2011; Szewczyk et al., 2013.
[9] Clarke et al., 2016.

in this group. At the beginning of the 2000's only five species were mentioned in this group[10], now the complex has 12 members[11]. The members of the complex are strongly different regarding their host niche, however their genetic similarities are above 99%[12]. In most of the cases *M. tuberculosis* is the infectious agent of human TB disease.

I.2. *Mycobacterium gordonae*

Mycobacterium gordonae is a non-tuberculous Mycobacterium, formerly called as *Mycobacterium aquae* and it could be isolated mainly from water and soil[13]. Although, this bacterium was earlier known as a non-pathogenic species[14], today it is rather considered to be the least-pathogenic mycobacterium[15]. Still as an opportunistic pathogen, examples can be found for human infections by nosocomial transmission and HIV co-infection as well as in rare cases, this bacterium can be also the causative agent of symptomatic pulmonary disease in immunocompetent individuals[16]. Due to its low pathogenicity and high presence in soil, this bacterium seemed to be ideal for serving preliminary results in lipid profile comparison with our method.

II. Material and methods

II.1. Cultivation and sample pretreatment parameters

The bacteria, isolated from clinical cases (*M. tuberculosis* 242; *M. gordonae*389/2018), were cultivated on Löwenstein-Jensen media (L-Asparagine; monopotassium phosphate; magnesium sulphate; magnesium citrate; soluble potato starch; malachite green; whole eggs; glycerol; demineralized water) for 3 weeks at 35 °C. After the incubation period, they were heated for 4 hours in physiological saline solution for the inactivation and were stored at −20°C after freeze-drying until use. The lipid extraction was carried out according to an earlier published method[17] with some modifications. Namely, the steps not required for mass spectrometric detection were excluded such as solid phase extraction and derivatization. Finally, the samples were dried in vacuum and resolved in 1mL of chloroform.

II.2. Instrumental analysis

The analytical measurements were achieved, on anUltimate 3000 UHPLC – Q Exactive Plus MS system (Thermo Fisher, US). For the sample introduction, the eluent is consisted of methanol and acetonitrile (8:2) supplemented with 5mM ammonium-formate. Five microliter of each sample was introduced via flow injection analysis into the HESI probe working in negative ion mode, while the data was acquired in scan mode. Our measurements were carried out with the following mass spectrometric parameters: 4kV, spray voltage;90V, S-lens voltage; the capillary, and the aux gas temperature was 400°C; the flow rate of the seath gas was 15 L/min, while it was 10 L/min for the aux gas. For the mass spectrometric optimization mycolic acid standard were used (from *Mycobacterium tuberculosis* [bovine strain], Sigma-Aldrich) and the taxonomical comparison 12 mycolic acids were chosen (Table1), which can be found in a higher

[10] Gutacker et al., 2002.
[11] Clarke et al., 2016; Coscola et al., 2013.
[12] Brosh et al., 2002.
[13] Mazumder et al., 2010.
[14] Picardeau – Vincent, 1999.
[15] Asija et al., 2011; Mazumder et al., 2010.
[16] Asija et al., 2011; Fujita et al., 2000; Mazumder et al., 2010; Resch et al., 1997.
[17] Hershkovitz et al., 2008.

ratio in the cell wall of the members of *Mycobacterium tuberculosis* complex based on the data of previous papers[18].

m/z	Short name	Molecular formula
1136.17	α-C78	$C_{78}H_{152}O_3$
1164.20	α-C80	$C_{80}H_{156}O_3$
1192.23	α-C82	$C_{82}H_{160}O_3$
1220.26	α-C84	$C_{84}H_{164}O_3$
1236.25	k-C84	$C_{84}H_{164}O_4$
1252.28	m-C85	$C_{85}H_{168}O_4$
1264.28	k-C86	$C_{86}H_{168}O_4$
1278.30	k-C87	$C_{87}H_{170}O_4$
1280.32	m-C87	$C_{87}H_{172}O_4$
1292.30	k-C88	$C_{88}H_{172}O_4$
1294.33	m-C88	$C_{88}H_{174}O_4$
1308.35	m-C89	$C_{89}H_{176}O_4$

Table 1.

Results and discussion

The mycolic acids were determined by the comparison of data from literature with the mass spectrum of mycolic acid standard and mycolic acid extract from *M. tuberculosis*. The determination based not only on the *m/z* value, but also the fragmentation pattern. The most typical and easily detectable fragment ions are derived from the α-chain of mycolic acids with the following *m/z* values: 339,367 and395[19]. Most of the mycolic acids – from the same group and with the same carbon atom number – could have 22, 24 and 26 carbon atoms long α-chain, and due to this the length ofthe β-hydroxy chain also variates (Fig. 1.) serving also an important taxon specific marker.

It was found that the mycolic acid profiles of the two investigated species comparing to each other showed remarkable differences (Fig. 2, 3). In the case of *M. gordonae* 389/2018 the C78 and C80 α-mycolic acids were dominant, which were approximately ¾ of the total area of the examined mycolic acids. Furthermore, all the examined α-mycolic acids were represented in 78%while the distribution of the keto- and methoxymycolates was proportionally decreased (Fig. 3). For *M. tuberculosis* 242, the α-mycolic acids were also detected at a high level regarding their relative ratios, but their yields reached only up to 45% of the total area (Fig. 2).The relative amounts of keto-mycolates andmethoxy-mycolic acids were 14% and 41%, respectively, while their yields were 6% and 16% in the case of *M. gordonae*. However, the oxygenated mycolic acids with higher molecular weight(k-C88; m-C88; m-C89) were less represented in both strains, butit was less than 1% of the total area in *M. gordonae*.

On the basis of the presented results we can presume that the used method could be sufficient to diagnose the presence of other members of *M. tuberculosis* complex in infections of past populations.

[18] Song et al., 2009; Shui et al., 2011; Szewczyk et al., 2013.
[19] Shui et al., 2011; Song et al., 2009; Szewczyk et al., 2013.

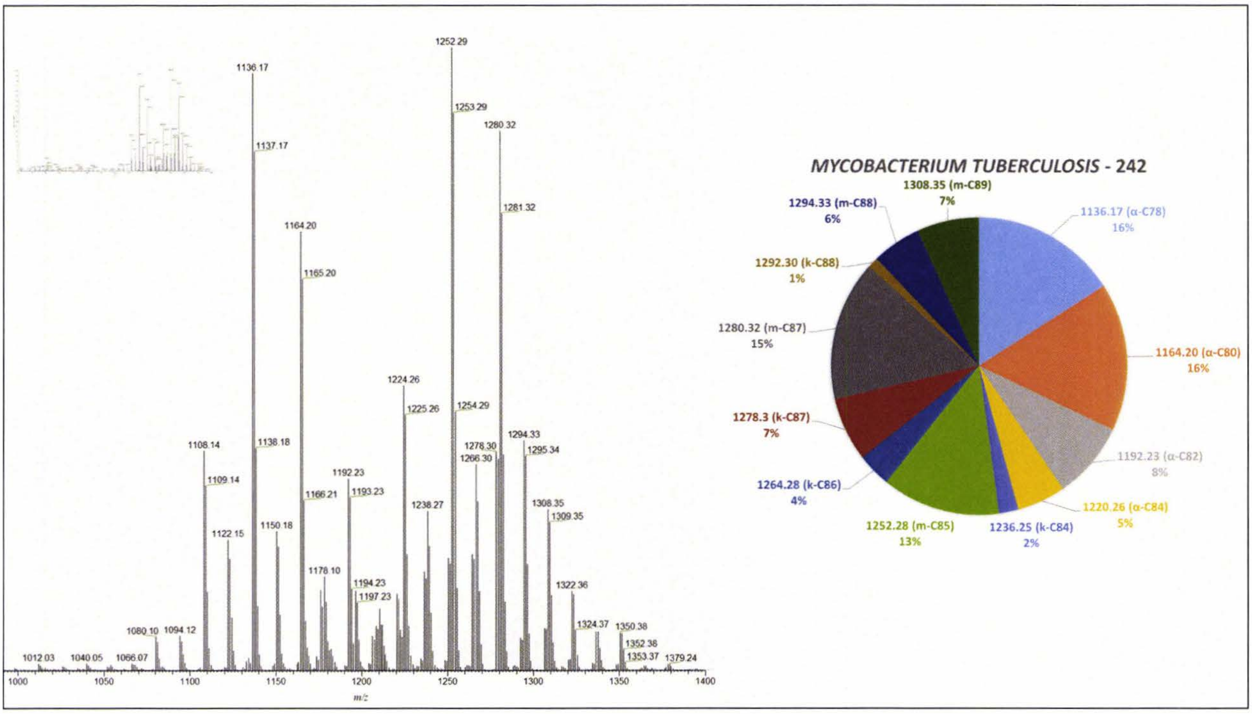

Figure 2.

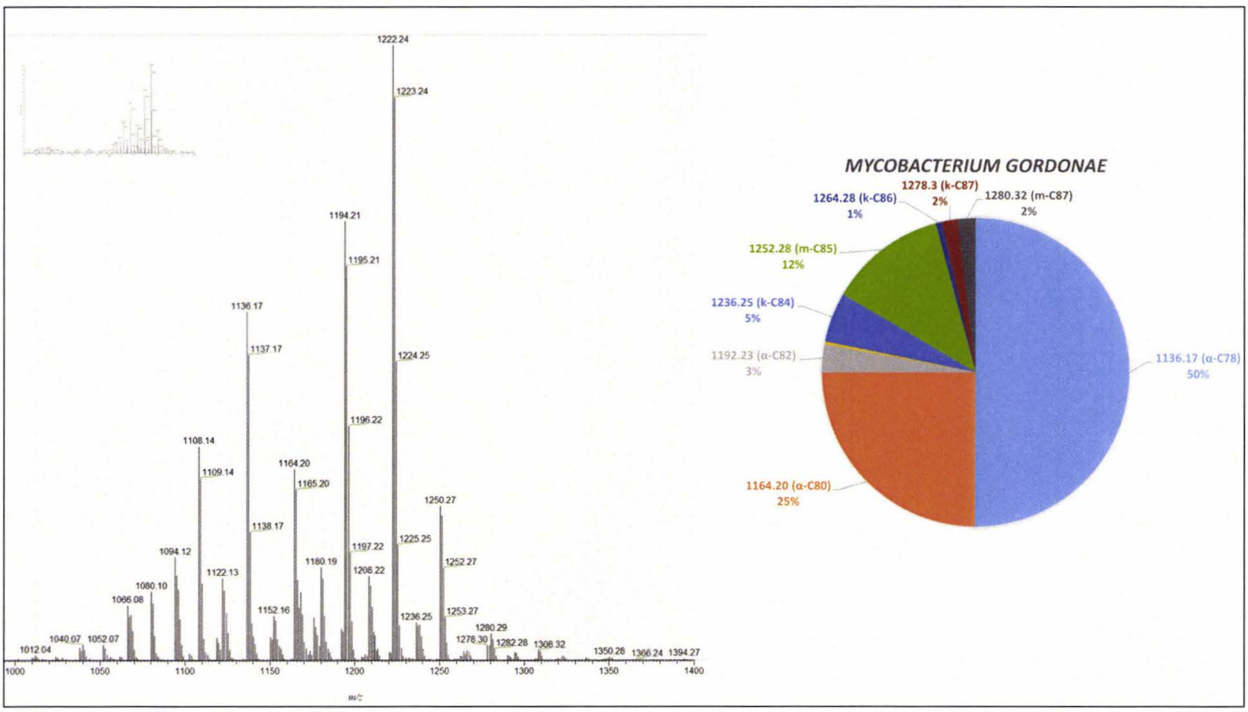

Figure 3.

Acknowledgments

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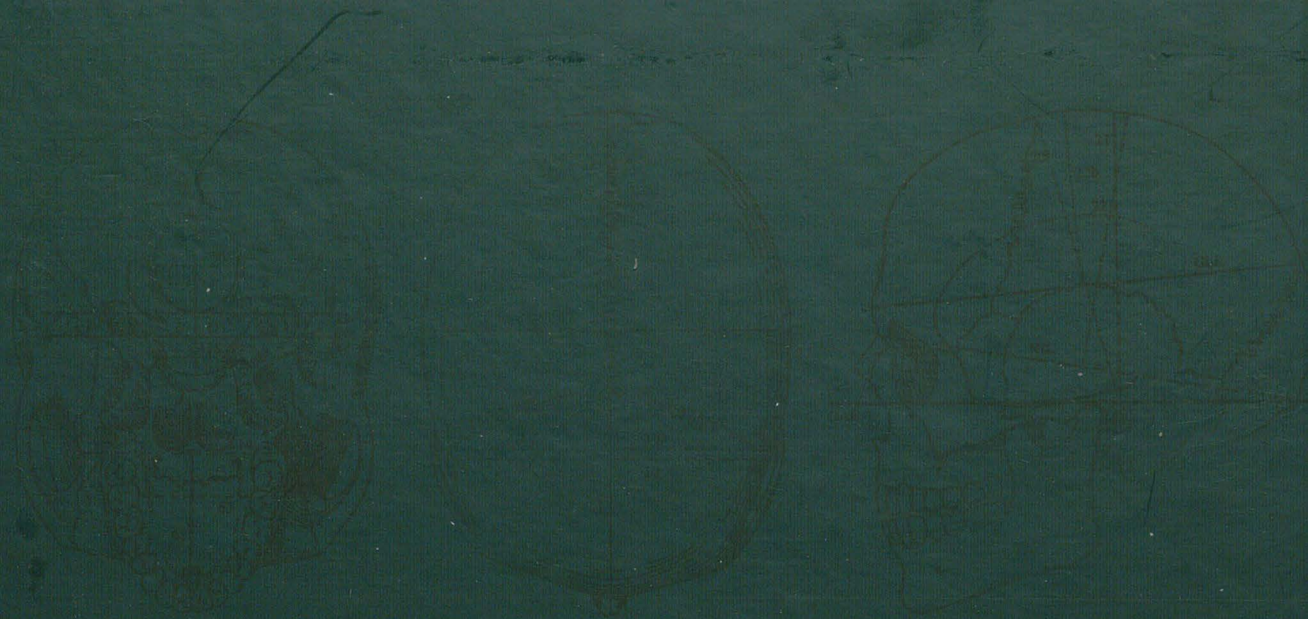
Figures

Fig. 1: Schematic structure of mycolic acids. A: C78 α-mycolic acid; C83 keto-mycolic acid; C84 methoxy-mycolic acid with C24 α-chain. B: C78 α-mycolic acid with C22, C24 and C26 α-chain.

Fig. 2: Mass spectrum of the extracted mycolic acids from *M. tuberculosis* and the relative ratios of the chosen marker mycolic acids.

Fig. 3: Mass spectrum of the extracted mycolic acids from *M. gordonae* and the relative ratios of the chosen marker mycolic acids.

Table 1: The *m/z* value, the short name and the molecular formula of the evaluated mycolic acids.



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