From Biography to Osteobiography: An Example of Anthropological Historical Identification of the Remains of St. Paul

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ABSTRACT
In the identification process of historical figures, and especially in cases of Saint’s bodies or mummified remains, any method that includes physical encroachment or sampling is often not allowed. In these cases, one of the few remaining possibilities is the application of nondestructive radiographical and anthropological methods. However, although there have been a few attempts of such analyses, no systematic standard methodology has been developed until now. In this study, we developed a methodological approach that was used to test the authenticity of the alleged body of Saint Paul the Confessor. Upon imaging the remains on MSCT and post-processing, the images were analyzed by an interdisciplinary team to explore the contents beneath the binding media (e.g., the remains) and to obtain osetobiographical data for comparison with historical biological data. Obtained results: ancestry, sex, age, occupation, and social status were consistent with historical data. Although the methodological approach proved to be appropriate in this case, due to the discrepancy in the amount of data, identity could not be fully confirmed. Nonetheless, the hypothesis that the remains do not belong to St. Paul was rejected, whilst positive identification receives support. Anat Rec, 300:1535–1546, 2017. © 2017 Wiley Periodicals, Inc.

Key words: paleoradiology; paleopathology; historical identification; St. Paul the Confessor; Vodnjan

INTRODUCTION
The Alleged Remains of St. Paul, Sixth Bishop of Constantinople and the Vodnjan Relics Collection

After the church of St. Blasius was built in Vodnjan in 19th century, Gaetano Gressler, an artist and arts collector, was invited to paint it. During that period, the revolution, which was negatively minded towards Christianity, spread across the Europe. After the fall of the Venice, Gressler brought the collection of sacral art, relics, and remains of the Saints (both mummified and skeletal remains) from Italy to Vodnjan, with intention to preserve it. Due to a contract with the pontiff of parish church of St. Blasius and city authorities, in 1818 he left them permanently to the church and municipality (Tomić, 1998; Jelenić, 2000; Škrobonja and Petaros, 2009). The exact number of relics and other valuable objects is still unknown, although it has been estimated that there are thousands of them.

St. Paul’s alleged body, which is kept in a church in Vodnjan, Croatia (Fig. 1) has been of interest to the...
scientific community for years. Saint Paul, also known as Saint Paul the Confessor, was the sixth bishop of Constantinople. His martyrdom happened in 350 or 351 AD, and as a martyr, he is important both for the Catholic and Orthodox Church (Butler, 1846). He is important in religious world, as he as a theologian was reputed to be a person that pervaded into the crux of the catholic faith. Moreover, his elucidation of faith is engraved in Constantinopolitan Creed and forms the foundation of present day Catholic faith. His body was first transferred to Galatia, and then to Constantinople in 381 AD where his remains were buried until 1226 when his remains were moved to the church of St. Laurence in Venice (Butler, 1846; Wace, 1911; Telfer, 1950). However, Venice did not become his final resting place, and his body was again relocated after the fall of the Republic of Venice to Vodnjan where it still rests today (Jelenić, 2000; Skrobonja and Petaros, 2009). In contrast to other cases from previous research, where alleged saints were excavated in the baroque era from the Roman catacombs and newly assembled in monasteries in Europe (Kristof et al., 2015; Alterauge et al., 2016), the after death journey of this Saint is better known.

Osteobiography in Historical Context

Osteobiography is a term deeply engrafted both in forensic and biological anthropology. However, there are many explanations of what this term really means and thus its definition largely depends the views and goals of the researcher (Saul, 1972; Robb, 2002; Boutin, 2012a,b). In biological anthropology, the term has a wide meaning and refers to an analysis and understanding of a broad range of events and life conditions. In practice, osteobiography commonly aims to reconstruct the lives of the general population, beginning with a detailed examination of an individual skeleton (Hamilakis et al., 2002; Boutin, 2012a,b). This is aligned with the first definition of osteobiography provided by Saul (1972). However, the real milestone was an interpretation of skeletal findings by comparison of an individual to a population of similar social or cultural context (Robb, 2002). This approach was also adopted in the forensic anthropology. For example, the famous forensic anthropologist Clyde Snow perceived the entire process of identification as the creation of biography of bones and considered that the skeleton comprises “a brief but very useful and informative biography of an individual.” He used this biography in cases of missing persons as the foundation for identification process that gradually eliminates individuals until the moment when a target person is found (Weizman, 2011).

The first step in osteobiography should always, when possible, start on the excavation site, where valuable data can be extracted from the example, burial ritual, findings inside a grave, privileged or unprivileged position inside the graveyard etc. Construction of the osteobiography is possible by visual and metric examination of skeletal remains, reporting distinguishable anatomical features and morphological variants of the skeleton to gather basic information about the person. It is usually focused on principal data about sex, age, ancestry, average body height, and then extended with examination of pathological conditions and trauma. However, constraints of the process are not only caused by the level of detail and the number of chosen variables but are affected by the manner of data interpretation. The interpretation of historical identification in this sense should be similar to forensic cases. The major difference is usually in the antemortem data, which in forensic cases usually reliable, and in historical sense, its authenticity should also be examined. Therefore, the key to the accurate data interpretation is understanding the biological processes and their cultural implications stemming from them. In this study, we propose a methodological approach for gathering historical and virtual anthropological data, valuable for historical identification. The majority of this data was pooled from anatomical “evidence”; information about social status, health and disease, habitual activities, level of physical labor, and traits that confirm a membership in particular
population in a given time and spatial frame were extracted, which ultimately lead to the identification.

**Literature Review**

In certain cases, the standard methods of biological anthropology can be used in the field to identify historical persons. The investigation of historical cases with human remains requires an implementation of various, relatively newly developed, methods. In the inception of such analyses, the applied methods were mostly traditional anthropological and osteometric methods that analyzed stature, occupational markers, trauma, health, and disease. In these “early” days of historical identification, for such analysis, a physical contact with bone was required (Martino, 1987). The historical identification case that occupied the public for many decades was the Romanov case that was finally solved in 2009 only with modern molecular techniques. As the results of the previously conducted anthropological analysis in this case could not be conclusive, additional mtDNA, autosomal and Y-STR testing was conducted providing irrefutable evidence that the remains do belong to two of the Roma- and Y-STR testing was conducted providing irrefutable evidence that the remains do belong to two of the Roma-

We have preliminarily reported the results of the analysis of the four bodies of saints from Vodnjan, including St. Paul (Andelinović et al., 2013). This preliminary study was the first one that provided insight into the alleged remains of St. Paul. However, at that time, the authenticity of the remains was not judged. To that end, the main goal of this study was to test the authenticity of remains by developing a methodology for comparing the results of historical findings and osteobiography gained by the nondestructive technique, that is virtual examination.

**METHODS**

**Research on Historical Data**

A comprehensive systematic literature search on the major web-based scholar databases (e.g., Web of Science) was conducted with no language restrictions applied. The search strategy included keywords: St. Paul, confessor, Constantinople, archbishop. Subsequently, relevant work cited in the retrieved articles and books was accessed from library resources. Only data relevant for constructing the historical biological profile were employed.

**Transport and Storing**

In 2011, the remains of the relics had to be transported more than 500 km for the purposes of the radiographic imaging to the Clinical Hospital Centre in Split, Croatia. At that time, the condition of the remains was unknown, special attention had to be given to the manner of transport. As the size of the sarcophagus was not appropriate for the opening size of the MSCT (Multi Slice Computed Tomography) device, a special procedure for transfer of the remains to a coffin adequate for MSCT was developed: a thin wooden laminate that enabled the transfer of the remains from the sarcophagus to a coffin without contact and destruction of the material was prepared. Additionally, special wooden coffins designed by the Croatian Conservation Institute in Zagreb were made in dimensions that allowed passing of the casket through the MSCT device (open bore: 70 cm).

**Imaging Procedure and Post-Processing**

The imaging was performed using an MSCT device, Somatom 16 (Siemens, Erlangen, Germany), with 16 rows of detectors and the spatial resolution of 30 lp/mm. The remains were spirally scanned in two parts (upper and lower) as the length of the coffin was 200 cm, which was longer than CT scanning length. Scanning parameters were 120 kVp, 162 mA, protocol — Body Angio Routine, Convolutional Kernel B30f. The slice thickness for the acquisition was 16 × 0.75 mm while for 2D images it was reconstructed to 3 mm.

2D images were post-processed by Multiplanar Reconstruction (MPR), Volume Rendering Techniques (VRT), and Maximum Intensity Projection (MIP) using software DICOM viewer, OsiriX v.3.9.4 (Pixmeo, Geneva, Switzerland). The Hounsfield (HU) values of attenuation
TABLE 1. Comparable historical and anthropological data

<table>
<thead>
<tr>
<th>Attributes from written and/or pictorial sources</th>
<th>Anthropological data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ancestry</td>
<td>Visual examination of the skull, osteometric data</td>
</tr>
<tr>
<td>Sex</td>
<td>Visual examination of pelvic and cranial morphology, osteometric methods</td>
</tr>
<tr>
<td>Age</td>
<td>Visual examination</td>
</tr>
<tr>
<td>Stature</td>
<td>Osteometric data and formulae for height estimation</td>
</tr>
<tr>
<td>Population affinity</td>
<td>Comparison of existing osteometric population data, epigenetic traits, cultural alterations</td>
</tr>
<tr>
<td>Physical appearance</td>
<td>Examination of specific traits, facial superimposition, facial reconstruction</td>
</tr>
<tr>
<td>Occupation</td>
<td>Muscular stress markers, osteodegenerative changes</td>
</tr>
<tr>
<td>Diseases</td>
<td>Markers of specific and nonspecific (infective) diseases</td>
</tr>
<tr>
<td>Injuries/Cause of death</td>
<td>Antemortem and perimortem skeletal trauma, distribution, lethality, injury mechanism</td>
</tr>
<tr>
<td>Social status</td>
<td>Orbital cribra, dental enamel hypoplasia, dental caries, nonspecific periostitis, Schmorl's nodes, osteodegenerative changes, trauma</td>
</tr>
</tbody>
</table>

coefficients were examined to determine the nature of the materials present.

The first step included the examination of contents beneath the binding media (casket, clothing, ornaments), that is, determination of virtual taphonomy. At that end, we had to remove the structures (overlaying material) that hindered the anatomical structures of interest and artifacts. From a complete volume of material and structures, using VRT (Volume Rendering Technique), and afterwards cutting the casket, clothing, ornaments, and artefacts, we created images for analysis and interpretation. Afterwards, the state of preservation of the remains was examined, with special attention drawn to the possibility of remaining soft tissue as well as the detailed inventory.

The research team consisted of three anthropologists (IJ, IK, ZB), one radiologists (SJ), one radiological technologist (FM), and one anatomical pathologist and forensic pathologist (SA).

Historical and Anthropological Analysis

Methodology for historical identification was developed in order to find comparable data from historical and biological sources (Table 1). The first column of the table shows attributes that need to be looked up in the written and/or pictorial sources, whilst the second is intended to explain how to find those on the skeletal remains.

Ancestry Estimation

The ancestry, that is, the classification into three major categories, was estimated by the analysis of cranial measurements (Moore-Jansen and Jantz, 1994) using Fordisc 3.1. (Ousley and Jantz, 2005) modern and ancient databases (Howells, 1973, 1989).

Sex Assessment and Estimation

The sex was assessed using standard anthropological methods, by examination of pelvic and cranial traits: greater sciatic notch (Walker, 2005), auricular surface of the ilium, presence of preauricular sulcus and parturition pits (Buijkstra and Ubelaker, 1994; White et al., 2011); and on skull a nuchal crest, mastoid process, glabella, supraorbital margin and mental eminence (Buijkstra and Ubelaker, 1994). The sex was estimated by examination of the ventral arc, subpubic concavity, and ischiopubic ramus morphology (Klales et al., 2012).

Age Estimation

Age at death was estimated by examination of cranial sutures, pubic symphysis, and auricular iliac surface, and the presence of osteodegenerative changes which correlate with age (Buijkstra and Ubelaker, 1994; Telmon et al., 2005; Thali et al., 2010; White et al., 2011; Iscan and Steyn, 2013).

Stature Estimation

Stature was estimated from the regression formulae (Trotter and Gleser, 1958) using the long bone length (Moore-Jansen and Jantz, 1994).

Occupational Stress Markers

Robusticity of long bones, musculoskeletal stress markers (Mariotti et al., 2007) and occupationally related nonmetric morphological variants were examined. For musculoskeletal stress markers only visible features were examined. When radiographical descriptions of such traits were available in current literature, the named were employed, for example in analyses of the proximal femur (Mellado et al., 2014). In cases when radiographical descriptions were not available, anthropological descriptions (Kennedy, 1989) were used instead, but lacking such radiographical norms, the features were used with caution and bones were thoroughly examined in different views and from different angles. Furthermore, occupationally related osteoarthritic changes (Sager, 1969; Jurmain and Kilgore, 1995; Mann and Hunt, 2005) were also examined.

Pathological and Traumatic Changes

Skeletal remains were also examined for pathological and traumatic changes, with special attention to those conditions that could be connected to the circumstances of death (life threatening diseases and perimortem trauma that can be identified on bones). In addition, skeletal markers of subadult stress (orbital cribra, dental enamel hypoplasia, Harris lines) were examined. The prevalence of cribra orbitalia to infer living conditions conducive to dietary iron deficiency, and iron loss from both diarrheal disease and intestinal parasites (Aufderheide and Rodriguez-Martin, 2011), and the latest research showed that it is probably caused by the lack of vitamin B12 or scurvy (Walker et al., 2009). Dental
enamel is very sensitive to metabolic disturbances, which result from poor quality of diet and various diseases. As dental enamel cannot be remodeled, dental enamel hypoplasia will remain as an indicator of subadult stress until the affected part of the tooth crown is destroyed by abrasion (Slaus, 2006). Harris lines or growth arrest lines are also a subadult stress indicator, visible on radiographs. These lines are a result of additional osseous deposition that results from the failure of continuous growth at the metaphyseal cartilage (Mann and Hunt, 2005). The scientific debate about the usefulness of this method is still ongoing, as it can show false positive as well as false negative results (Lewis and Roberts, 1997), but in this study, we are focused on the entire subadult stress “picture” instead of considering indicator separately.

In addition, the life quality markers (dental caries, periostitis, Schmorl’s nodes, osteoarthritis, traumas) were also examined (Sager, 1969; Ortner, 2003; Chhem and Brothwell, 2007; Aufderheide and Rodriguez-Martin, 2011).

RESULTS

Historical Biological Profile

Saint Paul was a white male who was born in Thessalonica at the end of 3rd century AD and died in his 50s (Jelenić, 2000), after at least 20 years of the priesthood (Telfer, 1950). During his time, he was forced into exile few times, and at the end, he was incarcerated and left to starve to death. However, after six days, when he was found alive, his enemies (followers of emperor Constantius and Ariana) strangled him and spread rumors that he had died of illness (Butler, 1846; Wace, 1911). Considering that he was highly ranked priest, at least most of his life, he was a member of higher society.

His occupation included praying and kneeling for long periods of time.

Inventory and Virtual Taphonomy

The visual examination of the body in situ revealed that the head of St. Paul was skeletonized, remains were dressed in bishop’s clothes and were lying down on a velvet red fabric, whilst the skull with bishop’s hat was positioned on the pillow. The remaining analysis was performed by MSCT imaging. Upon virtual removal of the layer of the binding media (by adjusting window level and width, and cutting off overlaying structures) it was visible that the remains were not mummified and that only the skeletal material was present. The parts of the skeleton were fixed to a wooden cross extending from the head to the lower limbs. A wooden cross was additionally fastened with a metal stick on the anterior side (Fig. 2). For the metal stick, the HU values on 3D MPR view showed values 3071 HU, in contrast to air (around −1000 HU) or wood (−400 to −600 HU). The cross was made by nailing the two boards with four nails.

The thorough examination of the bone inventory and position revealed that the skull was mostly preserved, although all of the teeth from the maxilla were lost post-mortem and the mandible was also missing. The visible facial/skeletal features were large frontal bone, laterally pronounced zygomatic bones, narrow nose, narrow maxilla, concave area on the level of the maxillary sinuses, asymmetric zygomatic bones (the right zygomatic bone in the bone was longer inferior-superiorly that the left one).

The left humerus was positioned medially–laterally, on the right side of the casket, whilst the right humerus was on the left side. The right radius and ulna were located on the right side and left ulna on the left.
The left ulna and the right humerus were post-mortem articulated. Near the left ulna, there were five metacarpals, all of which were protruding from the sleeve. The right radius and ulna were attached to each other by a stick and ribbon and tucked in the sleeve. On the anterior side, between the clothes and the remains, a little bottle was positioned (Fig. 3).

The left scapula was positioned on the right side while the right one was positioned on the left. The left clavicle was on the left side of the casket. On the same level of the upper limb, in the midline, there were 13 vertebrae through which the wooden stick was threaded (through the vertebral foramina). From the proximal to the distal part of the wooden stick, the vertebrae were lined up as follows: three lumbar, eight thoracic vertebrae, atlas, and the fifth lumbar vertebra. Several of the lumbar vertebrae were turned upside down. The sternal body was also visible aside the vertebrae on the left, and the manubrium, as well as xiphoidal process were postmortem absent. The ribs were enwrapped around the vertebrae and from anterior view seven ribs were visible.

The sacrum was positioned with the promontory lying on the wooden sarcophagus, whereas the posterior of the sacrum was faced anteriorly. The left acetabulum, postmortem articulated with the head of the left femur was on the right side and the right os coxae with right femur on the left side. Both of the coxal bones were placed with the pubic bone proximally. In the level of the pelvic griddle, left talus, left calcaneus, and both patellae were visible.

Both femora were positioned on the opposite side of the body with an anterior surface facing the back of the casket. Left tibia was situated on the left side of the body, and the right one on the right side. On the distal and proximal epiphyseal surfaces of the left tibia, metal rings were attached (Fig. 4). Besides the medial margin of the same tibia, the metal object was positioned.

The left fibula was located on the left side with distal part proximally, right fibula was not present. On the right side of the casket at the level of the lower limb, beside the tibia, one rib and two vertebrae (lumbar and thoracic) were positioned. The other foot bones were not present.

All long bones of the legs were positioned behind the wooden cross, that is, between the posterior casket cover and the cross, with only a part of the fibula protruding to anterior.

On the most distal part of the remains, two plates presenting the feet were put into the slippers (Fig. 5). No duplicate or non-matching bones were found. There were no deviation in morphological features and size of all examined bones.

**Ancestry Estimation**

The ancestry was classified as closest to white males using software Fordisc based on cranial measurements. The ancestry was classified as closest to white males in all cases: using the Forensic Data Bank, Howells database (in this case, it was closest to Norse population) and UTK black and white groups from 19th to 20th century.

**Sex Assessment and Estimation**

The nuchal crests were strongly pronounced, mastoid processes large, with several sulci, glabella was not pronounced, the supraorbital margin was thin and sharp. Greater sciatic notch was medium to narrow (Fig. 6), the auricular surface of the ilium was not elevated from the surrounding bone, and there were no visible preauricular sulci or parturition pits. Using the logistic regression equation (Klales et al., 2012) for sex estimation by the scoring of ventral arc (score 3), a subpubic concavity
(score 4) and medial aspect of ischiopubic ramus (score 4) the probability of being male was 94%.

**Age Estimation**

Examination of vault cranial sutures indicated the age range of 24–75 years and for lateral-anterior sutures the range of 32–65 years. The visual assessment of symphysis revealed that its outline was oval while surface showed no billowing. On the dorsal border slight lipping and on the ventral part a hiatus was visible. These features put the symphysis into the age range of 23–57 years (Fig. 6). All of the age relevant auricular surface features of the ilium features could not be examined due to imaging technology. Only the absence of billowing and moderate elevation of the rim were observed, which suggest the age above 35 years. According to all findings, estimated age range was 35–57 years.

**Stature Estimation**

The length of the left humerus was 309.3 mm; the height was estimated at 165.71 ± 4.05 cm. The humerus was chosen instead of the femur because imaging of the body was performed in two parts due to coffin size, which would require reconstruction and an increase in error.

**Pathological and Traumatic Changes**

All the vertebrae including the promontory of the sacrum showed signs of osteoarthritic changes (Fig. 7). Besides those changes, no other signs of pathological conditions or traumatic changes were visible.

**Occupational Stress Markers**

The examination of the physique revealed that the bones of the upper limb were less robust that those of the lower limb, muscular attachments on the lower limb were more pronounced. This was especially visible on the gluteal tuberosity, lesser trochanter, linea aspera, and on the greater trochanter, which was curved. Allen’s fossa and Poirier’s facet were also visible (Mellado et al., 2014; Fig. 8). The femoral intercondylar line, the groove from the posterior cruciate ligament, was strongly pronounced as well as the lateral squatting facet on the distal epiphysis (Trinkaus, 1975) (Fig. 9) and tibial imprint (Kostick, 1963). On the tibia, tibial tuberosity was also very pronounced, as well as the squatting facet on the distal joint surface. Overall, non-metric traits that were found indicate habitual equine riding and squatting/kneeling activities (Kostick, 1963; Trinkaus, 1975; Merbs and Euler, 1985; Kovacik et al., 2004; Wang et al., 2008; Andelinović et al., 2015).

**Comparison: Biography versus Osteobiography**

After collection of historical data and data obtained by anthropological analysis, the two data sets were compared and coincided for all available attributes (5/5). The remaining five attributes could not be compared due to missing data in one of the categories. Final results are summarized in Table 2.

**DISCUSSION**

In this research, we attempted to develop a reliable methodological approach for historical identification in cases where only un-destructive methods can be applied. Most of the previous studies that analyzed the bodies of the saints mainly focused only on the preservation and taphonomy (Kristóf et al., 2015); or reconstruction of a biological profile without possibility of thoroughly consulting historical records (Dedouit et al., 2014) and population data; or used destructive techniques for testing authenticity of the remains (Alterauge et al., 2016). Thus, only the studies that implemented destructive techniques could hitherto prove authenticity. This study is the first one that provides the methodology of non-destructive anthropological historical identification through gathering a significant amount of osteobiographical data.

As historical data is always scattered among historical context and historical significance of the person and is not easily approachable. This issue, that has shown to be a major shortcoming in aforementioned studies, we succeeded in circumventing by this novel methodological approach. We managed to extract biographical information about the ancestry, age at death, population affinity, physical appearance, most probable occupation related activities, the cause of death and probable social status. In addition, we obtained very informative biological data for comparison, that is, reconstruction of the osteobiography: ancestry, sex, age, stature, physical appearance, occupation, health, and social status. This novel approach enabled us to conclude that the hypothesis of positive identification, although it could not be fully confirmed, is highly possible.

First, the preliminary visual assessment indicated that the remains were skeletonized, all the bones were...
not in their anatomical position, and postmortem interventions were seen both on bones (adjustment with metal sticks, wooden sticks and plates, and ribbon) and other structures (the bottle, slippers with wooden plates). Because of that, we have a strong reason to believe that, at some point, someone has assembled the remains in the manner we see them today. The total number of bones in the assembly, the lack of super numerally bones, along with the bone morphology and size did not indicate that the skeletal inventory belonged to multiple persons.

The afterlife journey of this Saint is very well known. His remains were in Constantinople for an almost millennium, and only in 1226 were transferred to Venice. His final resting place is Vodnjan where the remains were translocated in 1818. Our case differed from other research that included Catholic saints, excavated in the baroque period from the catacombs and then
reassembled in monasteries (Dedouit et al., 2014; Kristof et al., 2015; Alterauge et al., 2016) in several ways. Namely, that there are a plethora of historical records that regard St. Paul’s aftermortem voyage, and therefore in any point of time, his body was not considered anonymous. The interventions visible inside the binding media and on skeletal remains could have happened only in two of his resting places–Venice or Vodnjan. However, the time when this happened could be answered in future studies that would include dating of artefacts and findings inside the casket through radiological images.

After obtaining virtual taphonomy data we compared the gathered historical claims and confronted them to the ostobiography.

Namely, from historical records, we learned that St. Paul was a white male who died in his fifth decade, and the osteobiography also revealed that the remains belong to a white male, whose age at death was estimated at 35–57 years. Considering ancestry estimation, we used Fordisc software, which has included database applicable for archaeological samples. Our goal was to estimate the affiliation to the three major ancestry groups, and use this to confirm or reject the historical data about Paul’s affiliation to a white population group. All of Fordisc run-ups (Forensic Data Bank, UTK groups, and Howells database), even though they did not contain Greek or biologically related populations, in all cases indicated that remains belonged to a white person.

Unfortunately, the biography lacked stature data and there were no pictorial sources from which stature could even be roughly approximated. Thus, the stature calculated from the bone length had to be excluded from further analysis. If the stature was available through pictorial sources the approximation could be done using the dimensions of objects of known size. The similar analysis could be performed if historical or pictorial sources provided information about the extreme height variation. For example, in our analysis of relics in the previous study, we discovered that one humerus belonging to un-proportional dwarf could be attributed to Saint Bartholomeus (Andelinović et al., 2013). However, even if we had the height data from an assumed population and status (in this case Greek upper society), we could conclude that he resembled an average individual from that time period and population.

The osteobiographical data also showed drawbacks: there were no previous craniometrics studies of his contemporaries that could corroborate the historical data about population affinity (nowadays Greece). If, for example, that data was available, we could examine if he “fit into” the metric data, and conclude if he was “an average” individual from a chosen population. Population affinity estimation could also be done by discriminant function analysis or principal components analysis, however, the current databases do not include Greek or similar populations. The study of epigenetic traits here could also be very valuable, but once again, the population data was scarce.

Regarding physical appearance, no written descriptions or relevant pictorial sources, such as drawings or sculptures, were found. A very useful method for these kinds of analyses, and according to some authors, the method that is put on the same level of forensic odontostomatology and molecular genetics could be craniofacial superimposition (Gaudio et al., 2016), but the drawback of this method is that it has proved to have false positive results. In addition, the realism of the work of art and the influences of the art period can be an additional source of error as every period has its own beauty standards and particularities, which can distort real appearance. Besides, it is difficult to confirm that the artist really knew what the person looked like.

These results should be considered in the light of the other findings, and not as a standalone method.
Furthermore, in the biography of Saint Paul we did not find any information that he had suffered from a specific disease. The same was found by the examination of the remains as there were no specific pathological changes except age and activity related changes. According to historical records, Saint Paul was tortured and in the end strangled. Unfortunately, the only bone that can indicate strangulation, the hyoid bone, was not present and therefore we could not consider that information. Signs of trauma were not visible, but it does not mean that the possibility of violent death could be excluded, as traces are often present only on soft tissue. As for most of his life Paul was a highly positioned figure, we have every reason to believe that he was not subjected to heavy physical labor. The osteobiographical data also supports this hypothesis as none of the considered markers were visible on his remains. In line with these findings, the discrepancy between the higher estimated age and severity of osteoarthritis also could be explained by higher social status. Finding of moderate osteoarthritis for an individual around 50 years is, in that time, uncommon as many of the contemporaries of that age, exhibited severe osteoarthritis due to heavy physical labor (Ortner, 2003).

Although osteoarthritis is considered to be age related, there are other factors that contribute to its development, such as mechanical stress and physical activity. The frequency of osteoarthritic changes and specific physical activities can be correlated, and both of these changes in archaeological populations are more valuable for indicating the quantity of labor needed for survival (Hough and Sokoloff, 1989; McKeag, 1992; Jurmain and Kilgore, 1995; Weiss and Jurmain, 2007).

In a comparison of biography and osteobiography, the markers of subadult stress can also be an extremely valuable source of information (Lewis and Roberts, 1997; Ortner, 2003; Mann and Hunt, 2005; Walker et al., 2009), but they were not found on the remains, thus indicating that he did not exhibit any evidence of subadult stress and probably had favorable living environment during childhood.

Data about everyday activities of Saint Paul were not available in written sources, but we can take into consideration that, as a bishop and prayerful man, he had spent significant amounts of time in prayer and kneeling. Upon examination of occupational stress markers, we have also found skeletal traits that argue in favor of this hypothesis. Particularly, lots of traits often named and attributed to “squatting,” were found. However, they also indicated habitual kneeling because of knee hyperflexion, which is common for the both of the activities. On the femur, these traits that are usually located in the distal part of the bone: lateral squattting facet on lateral epiphysis, groove on the intercondylar line, and tibial imprint were found. The first two traits result from the tension of cruciate ligaments during the knee hyperflexion. Particularly, during hyperflexion, an acute angle between femur and tibia is formed, and “being stabilized by the adductor muscles, while the posterior cruciate ligament tightly locks the knee” (Wang et al., 2008). In this situation, the posterior cruciate ligament is pressed against the anterior wall of the intercondylar fossa and intercondylar line, but also against the lateral wall covering anterior cruciate ligament. This posture can, over time, produce a groove on the intercondylar line and on lateral condyles additional squattting facet with a smooth surface located on the attachment of anterior cruciate ligament (Trinkaus, 1975; Wang et al., 2008). An additional trait, tibial imprints, found on the femur also have a similar cause. In fact, this trait is also the result of a knee hyperflexion firstly because of contact between the medial femoral condyle and the lateral posterior border of the tibial condyle (Kostick, 1963; Kovacik et al., 2004). Kneeling hypothesis is also supported by squattting facets that are found on the tibia, on the distal epiphyseal surface (Merbs and Euler, 1985).

Unfortunately, the foot bones that are also considered as valuable indicators of habitual kneeling posture were not present (Ubelaker, 1979; Ullinger et al., 2005).
(G. minimus, G. medius, and G. major), and in horse riding these muscles are important for maintaining the rider in the seat (Molleson and Blondiaux, 1994) and sometimes influence the morphology of greater trochanter (Andelovadin et al., 2015).

In contrast to the kneeling indicators, the Poirier’s facet and Allen’s fossa were clearer for diagnosis as they were already described in detail in the radiological literature (Mellado et al., 2014). Nonetheless, it is one of the common problems when interpreting MSCT images using anthropological criteria. It is because this type of imaging is still relatively new and research that compares anthropological standards on the dry bone with corresponding radiological indicators of findings are scarce. It is the case, not only when it comes to aforementioned non-metric traits, but also for numerous sex and age estimation and pathology diagnosis criteria. However, not all methods should always necessarily require corresponding radiological standards, particularly when it comes to interpretation of 3D reconstructed images. Especially, taking into account novel trends in the field of “virtual” or “computer-assisted” anthropology, which serves to explore “three-dimensional morphologic structures by means of digital data-sets of fossil and modern hominoids within a computational environment” (Weber, 2001). Weber (2001) points out that procedures for morphological analyses in a virtual environment does not differ considerably from traditional anthropological methods, but provides the means to obtain a more detailed analysis. Despite that fact, in our research, each finding was discussed by an interdisciplinary team, from anthropologists’, radiologists’ and forensic pathologist’s standpoint and then, the final conclusion was drawn.

Additional aggravating factors were imaging techniques and the antiquity of the bones. Particularly, 3D reconstruction and virtual examination was not easy due to the antiquity of the bones, which resulted in bone density decrease and consequently, a decrease in attenuation coefficient of the bones. Additional factors that hampered and prolonged the analysis were numerous artifacts and decorations on the clothing that obscured skeletal elements, which are why additional cropping and cutting was necessary to analyse the relevant anatomical structures. However, it cannot be excluded that one of the reasons was also the age of the individual.

The results of our study show that the suggested approach could serve as a framework for future historical anthropologic identification, not only in studies of relics but also in other studies that need to employ methods of biological anthropology for identification of historical figures. We have also shown that the identification relevant data could be obtained through both the osteobiography and historical biological records. Additionally, the comparison of various skeletal measurements and features to the assumed population from the same time frame can give a significant amount of additional information. We hope that even in cases when more conclusive and more destructive methods can be applied, the proposed approach here will be considered, and that its reliability will be validated.

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CONTRIBUTION OF THE AUTHORS

FM, IJ, IK, ŠA, SJ, ZB participated in study design and interpretation of data. FM performed MSCT imaging. FM, IJ, IK, ŠA, SJ, ZB conducted image analysis. FM, IJ, IK, ZB drafted the manuscript. FM, IJ, IK, ŠA, SJ, ZB revised the manuscript, and gave the final approval of version to be published.

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