COMPARATIVE ANALYSIS OF THE ACTIVITY-RELATED SKELETAL CHANGES OF INDIVIDUALS BURIED WITH WEAPONS IN THE 10TH CENTURY CE. BIOARCHAEOLOGICAL ASPECTS OF THE WEAPON-RELATED BURIAL CUSTOMS

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PhD THESIS

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INTRODUCTION

The aim of historical anthropology research is to give the biological reconstruction of different archaeological periods. One of the main elements of this biological reconstruction is the investigation of past lifestyle based on the so-called activity-related skeletal changes. In the last decades, these investigations provided the only primer sources of past lifestyle and activities in certain cases; thus, allowed the extension of knowledge on both anthropological and archaeological problems. The complex bioarchaeological analysis allowed researchers to re-evaluate the possible meanings and symbolism of the weapon-related grave-goods and burial customs.

The activity-related skeletal changes include many features on the cranial (e.g., tooth wear) and postcranial skeleton, such as entheseal changes (at the insertion sites of tendons and ligaments), joint changes, traumatic lesions, and bone geometry, which are the most frequently studied parameters. The investigation of activity-related skeletal changes started to develop and spread in biological anthropology and paleopathology in the 1980's, and recently it became one of their main research fields. Despite the increased research, the link between the actual activity and the skeletal changes is still not clear. The activity-related changes, such as entheseal changes and joint changes, belong to a wider group of lesions, and other non-mechanical factors (e.g., genetics, sex, age, and metabolic disorders) can also influence their development. Thus, researchers must take great care when selecting pertinent materials and methods to avoid possible overinterpretation. Knowing these limiting factors, the archaeological context (i.e., the grave-goods and burial customs) is still determinant for studies aiming the investigation of the lifestyle of past populations and archaeological cultures. However, the possible meanings of the grave-goods and certain burial rituals, whether they reflect the past life, are a controversial issue. Grave-goods were provided by those who laid the dead to rest; and therefore, they might rather reflect the wealth, social status, and religious beliefs of the family and the society. Thus, evaluating the past lifestyle and possible 'occupation' (e.g., warrior or 'civil') based on the presence or absence of a certain type of grave-good, such as the weapons, can lead to misinterpretations.

Regular practice with given types of weapons can lead to the development of various skeletal traces, which provides the basis for the investigation of activity-related changes. In the last decades, several studies focused on the possible skeletal traces of practicing with different types of weapons, such as atlatl or bow. Besides, recent studies started to aim the comparative statistical analysis of the burials with weapons on the population-level. In Hungary,

investigation of activity-related skeletal changes has also been conducted in the last decades. However, the systematic activity-related analysis of the burials with weapons from the 10th and11th-centuries CE, corresponding to the so-called Hungarian Conquest period of the Carpathian Basin, is yet to be accomplished.

The Hungarians were involved in many conflicts in the 9th and 10th centuries, and consequently, in violence and war situations that underlines the importance of the warrior class in their society. The written sources and archaeological material clearly show that the Hungarian army consisted of soldiers trained for melee and range combat, but mounted archers played, indeed, the most important role in their tactics. Objects and rituals related to interpersonal violence and warfare can also be found in the archaeological material of the 10th-century-CE of the Carpathian Basin: different types of axes, spears, sabres, swords, sabre hilted swords, and elements of archery equipment were described. The frequency of these weapons in the graves is not even, and the elements of archery equipment can be found much more frequently in the graves from this era. The evaluation of the weapon-related grave-goods is complex, since there is no link between the number and composition of the weapons in the graves and the possible military rank. Besides, the climatic and soil characteristics of the Carpathian Basin allow mostly the preservation of inorganic materials only; thus, certain weapons could be destroyed in the soil without a trace. Although weapons and graves with weapons are characteristic parts of the archaeological material of the Hungarian Conquest period, these are still rare phenomenon compared to the total number of graves and cemeteries from the 10th–11th centuries CE. Moreover, the evaluation of the possible military potency of a population is still based on the number of graves with and without weapons in the cemetery.

The tactics and fighting style described by the written sources and archaeological material required systematic practice and special training, which makes the anthropological material of the Hungarian Conquest period perfect for the study of activity-related skeletal changes. Although the sports medicine and anatomical evaluation of practicing with different melee weapons requires further investigations, the dominance of archery allows us to address the problem.

Numerous sports medicine, sports traumatology, and biomechanical studies focused on archery, since the reputation of this sport is highly increasing. Archery is usually defined as a static movement that requires the strength and stability of the upper body and especially the shoulder girdle and the forearm. Physical fitness is determinant for the archer to resist the physical loading while drawing the bow. The position of the arms and the trunk is crucial, since it influences which muscles are forced with increased load compared to others. According to

recent studies, the muscle activation profile shows differences between the individuals, since the shooting process is determined not by a single muscle but the complex work of the trunk and arm muscles. Therefore, archers need special trainings for the ideal strength and endurance level of these muscles; thus, they can delay the occurrence of fatigue effect, which is one of the main risk factors of injuries in archery sport. In summary, specially trained muscles are needed if someone aims to successfully practice archery on the elite level for years. Anatomical data supported the hypothesis that the Hungarian Conquest period material provides an excellent basis for anthropological research. Besides, knowing the list of these muscles and joints allowed us to determine which bones and features should be involved in the anthropological analysis.

THE OBJECTIVES OF THE DISSERTATION

We started our research in 2015, connected to the workshop of the Department of Biological Anthropology and Department of Archaeology of the University of Szeged. The main question of our investigation was if we can identify a marker or a set of markers which helps, even without the related grave-goods and burial customs, to determine and describe the characteristics of those, who repetitively practiced with weapons, and especially archery. The anthropological, archaeological, and sports medicine background highlighted the complexity of limiting factors and that the analysation of single muscles or one specific topic (e.g., entheseal changes) is not a sufficient way of research. The use of a complex method, which involves all the necessary topics, is required. Based on the above introduced perspectives, the main objectives and questions of the dissertation split into two groups.

1. Anthropological and methodological aspects

The main goal of this research is to contribute to the bioarchaeological knowledge on the burials with weapons from the 10th-century-CE Carpathian Basin by registering relevant activity-related skeletal changes that can help in the description and characterisation of the osteological parameters of these individuals in the future. Therefore, we aimed to register possible skeletal markers, which help to determine the group of individuals with weapons, and to find the relevant methods, which are suitable for the analysis.

2. Evaluation of the data in the social archaeological context

The other main goal of the dissertation is the discussion of the results in the archaeological context. The comparative analyses of groups with and without weapons might result valuable and new information for the social archaeological aspects. The evaluation of possible similarities and differences between the two groups allows us to access new information concerning the recognition of the factors that influenced the weapon-related burial customs.

MATERIALS AND METHODS

The primer research material was selected from the 10th-century-CE cemetery of Sárrétudvari-Hízóföld. This cemetery is the largest known cemetery from this period and contained graves with horse riding- and weapon-related deposits in a high number. Based on the analysis of the artefacts and burial customs, the cemetery was constructed by several groups of burials. Despite the minor differences between these groups, the population can be considered as one cultural group, and the armed group is consistent with the general characteristics described by the archaeological and historical sources related to the warriors from this era. Besides, earlier anthropological studies registered specific pathological and non-pathological changes in this series, for which it became the long-term subject of different studies, including the investigation of activity-related skeletal changes (e.g., lesions possibly related to horse riding). To decrease the effect of non-mechanical factors, only adult males were included to the investigation. From certain types of analysis, individuals above 50 years of age were also excluded. Similarly, cases with pathological changes on the skeleton that could influence the development and evaluation of the activity-related changes were also excluded. We divided the individuals into two subgroups according to the presence ('armed') or absence ('unarmed') of weapon-related grave-goods. Depending on the type of analysis, up to 38 individuals from the armed group (ARM) and up to 29 from the unarmed group (UARM) could be included to the evaluation.

Our preliminary results indicated that the unarmed Sárrétudvari group might contain individuals, who had similar lifestyle to that of the armed individuals. In extreme conditions, the two Sárrétudvari groups can highly overlap with each other. Thus, we selected an independent, modern (19th–20th centuries) comparative sample to the investigation that consisted of 47 individuals with known age, sex, and occupational data from the Luís Lopes anthropological collection of Lisbon (LIS). Inclusion of an independent population of individuals with heavy work, which was different from the activities of the armed individuals, allows us to discuss the results even if the two Sárrétudvari subgroups had the same lifestyle.

We followed a combined methodology, composed of five categories: entheseal changes, joint changes, metric indices of shape and robusticity, morphological variants, and traumas. The selection of the variables was based on anthropological, anatomical, and sports traumatological data, and the main bones of the upper limb (i.e., scapulae, claviculae, humeri, radii, and ulnae) were the subject of the analyses. In addition, we extended the analysis of traumatic lesions to the skull, ribs, and bones of the lower limb, since the injuries related to horse riding and interpersonal violence can affect any part of the body.

We performed comparative statistical analyses to evaluate the data. To avoid bias related to the low sample size and to ensure the homogeneity of the results, we used only non-parametric test for both the intergroup comparison and the tests of directional asymmetry (differences between the right and left side values).

RESULTS AND DISCUSSION

1. Among the different qualitative categories, entheseal changes were the most frequently registered. The armed group (ARM) showed higher frequencies (10 of the total 21; right (R) and left (L) sides counted together) concerning most of the entheseal changes. We registered statistically significant differences between groups in the case of 25 formations (L, R or L+R) of 11 entheses (out of the total of 21). Although we did not find significant differences between the two Sárrétudvari groups, we observed significant differences between the Sárrétudvari groups (ARM and UARM) and the Lisbon group. The directional asymmetry tests revealed that the values appeared mainly bilaterally (independently from the presence/absence of the changes), and in the case of asymmetrical changes, the right side was dominant. Summarising the results, we noticed that significant differences were mostly registered in the case of those entheses, where: either the armed group showed changes in the highest frequency or the frequency of the changes was higher than 50% in the armed group. Knowing the anatomical properties, we claim that no entheseal changes observed on the bones are specific by themselves to one activity, but the set of these entheseal changes has great potential concerning the further analysis of the armed group. Muscles attached to these entheses are highly involved in movements and activities (e.g., throwing, shooting with a bow, and sword fighting), which are characteristic to the warriors of the Hungarian Conquest period. The directional asymmetry tests of the entheseal changes revealed that the two-handed physical activities were dominant in all three groups. Although other non-mechanic factors can lead to the development of bilateral changes, our results are consistent with the results of international studies, which observed bilateral characteristics of individuals with weapons, and especially with archery equipment. Besides, kinetic studies in archery also highlighted the bilateral activity of muscles during the shooting process.

2. We observed joint changes in a lower number of cases possibly due to the age-related restrictions that we used for this study. The armed group showed the relatively highest frequency of the changes concerning most of the joints (5/7; left and right values counted together). The changes appeared in higher frequency in the shoulder girdle and elbow, and especially in the *articulatio acromioclavicularis* and *articulatio cubiti*. Despite the intergroup

differences, we registered a statistically significant difference only in one case, but even the pairwise analysis could not identify between which groups. The results of the directional asymmetry tests show that the values were mainly bilateral (independently from the presence/absence of the changes), similarly to the results of the asymmetry test of entheseal changes. Additionally, the right side was dominant concerning the asymmetrical cases. The tests revealed a change in the asymmetry tendencies of the armed group, since *articulatio glenohumeralis* showed rather left-side dominance, while *articulatio cubiti* showed rather right-side dominance. Although joint changes appeared in a low number and did not show any statistically significant difference between the groups, they may still be an important tool in the future research in combination with other types of changes. The armed group shows, indeed, rates which correlates well with the high number of entheseal changes. In earlier papers, some entheseal and joint changes of the shoulder and elbow regions have already been associated with the practice of archery. Additionally, these results also support the hypothesis that the two-handed physical activities were dominant in all three groups.

3. Morphological variants involved in the analysis appeared only occasionally in the three groups despite the higher number of individuals in all groups. Although *os acromiale* appeared in a relatively higher frequency in the armed group, statistical tests did not reveal significant differences between the groups. We did not find any significant difference between the groups concerning the other types of morphological variants either. The tests of directional asymmetry showed bilateral values and we could not register any statistically significant difference between the groups. Earlier studies suggested a link between the development of *os acromiale* and the long-term practice of archery. However, *os acromiale* and the other types of the analysed morphological variants are not suitable for discussing activity-related skeletal markers in the armed group.

4. We registered traumatic lesions in 14 cases of the armed group, in 10 cases of the unarmed group, and in 14 cases of the Lisbon group. The upper limb bones were affected most frequently in the armed (31.58%), unarmed (20.69%), and Lisbon (12.77%) groups, followed by the lesions of the thorax (10.34%, 5.88%, and 11.36%) and the lower limb (5.26%, 10.34%, and 8.51%) bones. We found traces of politraumatism in 10 cases (6 ARM, 2 UARM, and 2 LIS). Intergroup analyses revealed statistically significant differences concerning the *clavicula* traumas. Although the pairwise analysis resulted in differences especially between the ARM and LIS groups, only one *clavicula* trauma case could be found in the UARM group. Traumas of the *clavicula* are mostly caused by falling from a height, which is especially the case in the practice of horse riding. According to written and archaeological sources, most of the

individuals with weapon were also riders, which is supported by the relatively high number of *clavicula* traumas. Our results are parallel with the results of studies focusing on the horse riding-related skeletal changes, which also concluded that the high frequency of *clavicula* traumas in the Sárrétudvari population is in connection with the horse riding-related lifestyle. These results support that further investigation of *clavicula* traumas is important for studies focusing on the osteological characteristics of mounted archers (in our definition, the mounted archers are individuals, who were regularly practicing archery and other combat styles from horse back).

5. Comparative analyses of metric indices were also conducted for both the right and left side bones separately and combined. Statistical tests revealed significant differences in a high ratio, in the case of 9 indices from the total of 14 (*scapula*: 1, *clavicula*: 2, *humerus*: 2, *ulna*: 1, and *radius*: 3 indices). Although statistically significant differences were mostly observed between one or both Sárrétudvari groups and the Lisbon group, the robusticity index of the *clavicula* showed also statistically significant difference between the two Sárrétudvari groups. Besides, statistically significant differences were observed in the cases of 3 indices between the ARM group and the LIS group and in the cases of 3 indices between both Sárrétudvari groups and the LIS group. Directional asymmetry tests described different patterns in the three groups. Asymmetries were found in the highest frequency in the ARM group: the analyses of 6 indices (out of the total of 14) revealed a statistically significant difference between the right and the left side bones. In the UARM group, the analyses of 3 indices, while in the LIS group, the analyses of 4 indices revealed statistically significant differences between the sides. Concerning the armed group, the results indicate that the *cavitas glenoidalis* is wider on the left side, while the anterior bending of the *clavicula* and the robusticity of the *clavicula*, *humerus*, *radius*, and *ulna* is higher on the right side. The asymmetry patterns were different inside the groups; thus, we performed further tests to evaluate the relevance of these differences on the intergroup level. However, we could not observe any statistically significant difference between the groups.

According to anthropological, sports medicine, and biomechanical studies, all these statistically relevant indices can be explained with the repetitive practice of physical activities, including archery. Although the asymmetry tests of the qualitative variables suggested the practice of two-handed activities in the ARM group, the analysis of the quantitative variables highlighted a slight right-side dominance. Sports medicine and biomechanical studies described the symmetric, bilateral patterns of archery. On the other hand, earlier osteometric studies on burials of medieval warriors concluded that the repetitive use of different types of weapons, such as the bow and melee weapons, can develop differences concerning the directional

asymmetry patterns of the individuals, and archery can result in rather symmetric, while practicing with melee weapons, such as the sword, can result in rather asymmetric values. Based on our results and the related literature, we assume that the individuals from the Sárrétudvari armed group practiced both activities with bilateral load, including archery, and activities with unilateral load, including the use of melee weapons.

CONCLUSIONS, RESEARCH SIGNIFICANCE, AND PERSPECTIVES

We registered numerous statistically significant activity-related skeletal differences between the ARM, UARM, and LIS groups. Our conclusions related to the analysis of entheseal changes, joint changes, morphological variants, traumatic lesions, and metric indices of shape and robusticity can be categorised into two main groups.

1. We found minor changes between the armed and unarmed Sárrétudvari subgroups. Concerning the unarmed group, we observed higher frequency of the changes at the shoulder girdle, and especially in the *clavicula*, while the armed group showed higher rates of changes both at the shoulder and elbow regions. On the other hand, among all the analysed entheseal changes, joint changes, morphological variants, traumatic lesions, and metric indices of shape and robusticity, we observed a statistically significant difference between the armed and unarmed group only in the case of the robusticity index of the *clavicula*. We assume that the lack of a statistically significant difference between the two subgroups refers to the (at least partially) similar lifestyle of the armed and unarmed Sárrétudvari groups.

2. Most of the variants that were involved in the analysis have a multifactorial aetiology; thus, their development is influenced by genetic and other environmental factors. Although we must take population-level differences into account when evaluating the results, the chosen qualitative and quantitative variants are widely used in the anthropological and paleopathological studies to analyse and describe general or specific activities. Although on the current level of our investigation, it is not possible to decide if the differences occurred by population- or activity-related factors, the following markers are still important for future research:

- *scapula*: length-width index of *cavitas glenoidalis*;
- *clavicula*: entheseal changes of *lig. conoideum*;
- *humerus*: entheseal changes of *m. latissimus dorsi/m. teres major*, *m. pectoralis major*, and *m. brachioradialis/m. extensor carpi radialis longus*;
- *radius*: index of robusticity and index of distal *epiphysis* width; and

- *ulna*: entheseal changes of *m. supinator*.

The results allowed us to identify several activity markers, which are assumably related to the lifestyle of the armed group, including the practice of archery and other fighting techniques. The following markers belong to this set:

- *scapula*: asymmetry patterns of the length-width index of *cavitas glenoidalis*;
- *clavicula*: entheseal changes of *m. deltoideus*; traumatic lesions of the *clavicula*; index of robusticity and asymmetry patterns of index of robusticity; and asymmetry patterns of index of curvature;
- *humerus*: cross-sectional index of *caput humeri* and asymmetry patterns of index of robusticity;
- *radius*: entheseal changes of *m. biceps brachii*, cross-sectional index of the *diaphysis*, and asymmetry patterns of index of robusticity; and
- *ulna*: entheseal changes of *m. brachialis* and *margo interosseus*, cross-sectional index of the *diaphysis*, and asymmetry patterns of index of robusticity.

Although the above described set of markers is not yet suitable for the identification of warriors on the individual level, the comparative statistical analysis and the presence of these markers allow us to detect the activities, which are characteristic for the armed group inside a population or between populations.

Our results concerning the identification of the armed group and the possible relationships between the armed and unarmed groups allow us to draw conclusions that are informative for field of archaeology, as well.

1. Concerning the connections between the armed and unarmed groups, the anthropological research revealed that the individuals without weapon-related artefacts in their grave were practicing (partially) similar activities. The distribution of the statistically significant differences between the groups suggests that the unarmed group could contain individuals, who practiced similar activities to that of the armed individuals. Consequently, in the case of the Sárrétudvari-Hízóföld cemetery, the lack of tweapon deposit does not reflect properly the past lifestyle; thus, evaluating the military potency of the population by comparing the ratios of the individuals with and without weapons in their graves is not a sufficient way.

2. The methods used for the analyses were suitable for detecting relevant activity-related differences between the groups. Thus, involving more cemeteries to the investigation and extending the research on the micro-regional level can allow us to distinguish and to select areas, where the activity-related changes confirm the concentration of the ‘warrior class’. This

type of analysis opens new perspectives concerning the localisation of possible power centres in the Carpathian Basin. Besides, further opportunities arise by the investigation of larger cemeteries dated to the 10th and 11th (or even 12th) centuries CE. The comparative analysis of different periods of the same cemetery allows us to detect possible changes in the lifestyle through time. Written and archaeological sources indicate that a military-reform was conducted in the Hungarian army at the turn of the 10th and 11th centuries CE, and the eastern type army was exchanged by western type tactics and formation. However, the details of this process (e.g., the differences between the regions) are not yet clear, which makes the activity-related research even more important.

The anthropological and bioarchaeological identification of armed individuals results in information on the level of the single graves and burials, which basically influence the possible evaluation of the cemeteries. Investigation of burial customs of the 10th and 11th centuries CE is a complex but insufficient research field; thus, every single data extends and refine our knowledge on the topic. Anthropological data concerning the Sárrétudvari-Hízóföld series proved that the lack of weapon- and, in parallel, horse riding-related grave-goods does not reflect properly the past lifestyle. Therefore, these artefacts are part of a complex burial custom, which was influenced not only by the connected lifestyle.

LIST OF PUBLICATIONS (MTMT ID: 10053309)

1. THE 2 PAPER PROVIDING BASIS FOR THE THESIS

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