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ARTICLE

Investigation of Hungarian Conquest Period (10th c. AD) archery on the basis of activity-induced stress markers on the skeleton – preliminary results

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ABSTRACT In this paper we introduce the preliminary results of an anthropological investigation of archery-induced stress markers on the skeletons of a Hungarian Conquest Period cemetery. According to historical and archaeological data the bow was a common weapon in this era. Our main question is whether anthropological data also reflect this fact, or not. We focused on entheseal changes that occur on the skeleton as a result of physical stress. Macroscopic analysis was performed of the scapulas, claviculas, humeruses, radiuses and ulnas of the "archer" graves and the unarmed adult male graves. We found hypertrophy at the attachment of a wide scale of muscles of the upper body and a few of them - such as *m. deltoideus*, *m. pectoralis major*, *m. latissimus dorsi*, *m. brachialis* and *m. biceps brachii* - appear in high frequency. As a preliminary result we can state that the anthropological and archaeological data do support each other concerning the application of archery in the population in question.
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activity-induced skeletal markers
archery
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Introduction

It has been known for long that different traces of physical activities can be detected on the human skeleton and basic studies has already been conducted back in the 16th century AD (Kennedy 1989). However, the paleopathological investigation of the activity-induced stress markers has only become widespread in the 1980's (Merbs 1983; Stirland 1984; Dutour 1986). Meanwhile, sports traumatology and physiopathology of the muscular insertions (Clement et al. 1984; Lott et al. 1987; Rodineau and Simon 1987; Hess et al. 1989; Simon et al. 1991) have also developed considerably. Paleopathologists started to use these markers to reconstruct past life activities (e. g. Kennedy 1989; Merbs 1989; Bridges 1990; Stirland 1991, 1998; Dutour 1992; Hawkey and Street 1992; Lai and Lovell 1992; Pálfi 1992; Hawkey and Merbs 1995; Pálfi and Dutour 1996; Peterson 1998; Robb 1998; Steen and Lane 1998; Capasso et al. 1999; Al-Oumaoui et al. 2004; Eshed et al. 2004; Molnar 2006, Alves Cardoso and Henderson 2010, Villotte et al. 2010; Havelkova et al. 2011; Thomas 2014). However, the link between the actual activity and the skeletal markers is not yet clear (Dutour 1992; Robb 1998; Jurmain 1999; Pearson and Lieberman 2004; Villotte 2008; Jurmain et al. 2012; Thomas 2014). The complexity of the problem is reflected in the diverse terminology for entheseal changes, for example: enthesopathies (Dutour 1986), muscle markings (Robb 1998) or musculoskeletal stress markers (MSM) (Hawkey and Merbs 1995). Enthesopathies are a wider group of lesions (discussed by Villotte et al. 2010) and may not be exclusively caused by mechanical factors, but may also depend on age, sex, or other pathological changes (e.g. DISH) (discussed by Thomas 2014).

The group of activity-induced skeletal markers can be classified from different perspectives (Dutour 1992; Kennedy 1989; Villotte 2006). According to the type of the activity, there are two main groups: one-off activity markers and systematic, repeated activity markers. One-off activity appears in a single and accidental occasion, like most traumas (fractures and sprains). This group is not giving any information about the usual activities of the individual, but may give good background information about the individual's life history (fighting wounds, Parry-fracture, etc.). Certainly, the second group is more informative about the regular activities of the individual, but can be problematic too. There are specific and non-specific markers and it is often hard (or impossible) to differentiate between the two groups (Cooper 1995; Pálfi and Dutour 1996). In case of non-specific or "primary"

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Table 1. Muscles usually involved in the shooting process.

Site	Muscles
Body	*m. serratus anterior, m. pectoralis minor and major, m. rhomboideus minor and major, m. latissimus dorsi, m. trapezius, m. levator scapulae*
Shoulder	*m. deltoideus, m. supraspinatus, m. infraspinatus, m. teres minor and major, m. subscapularis*
Arm	*m. biceps brachii, m. brachialis, m. triceps brachii*
Forearm	*m. flexor digitorum, m. flexor digitorum profundus, m. flexor pollicis longus*

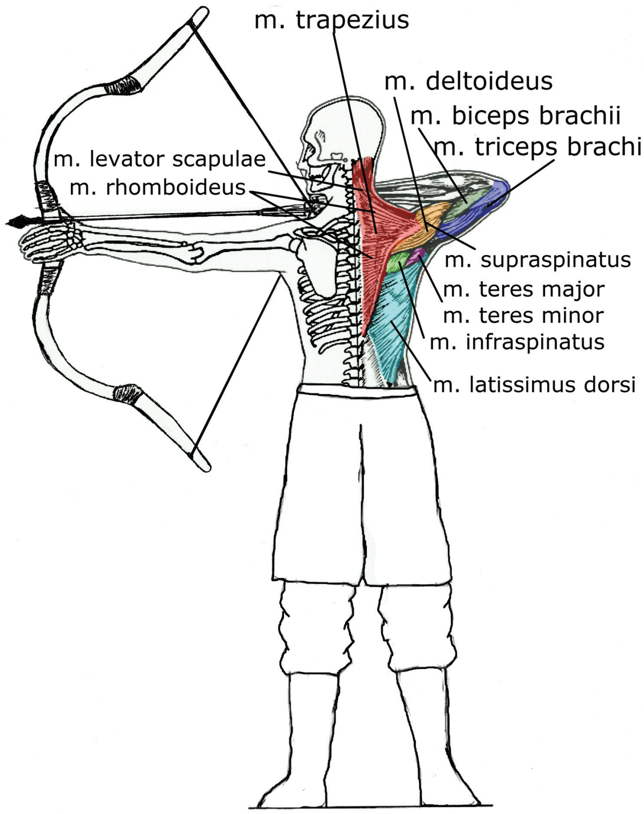

Figure 1. The anatomy of archery. Archery from the viewpoint of the usually involved muscles (after Axford 1995 with modifications).

markers, precise aetiology cannot be diagnosed (Pálfi and Dutour 1996), while specific or "secondary" markers do have a precise aetiology (Verrouil and Maziéres 1995; Pálfi and Dutour 1996).

There are many possibilities to investigate the specific activity-related stress markers, but limitations of the research are also obvious and we must avoid possible over-interpretation of our findings (Pálfi and Dutour 1996). Archaeological and historical context must always be the basis of these studies. On the other hand, the interpretation of archaeological findings has its own limits too: it is always a controversial issue whether the grave-finds are the mirrors of life or symbolic (Härke 1997). Grave goods are provided by the family and the community, so they reflect wealth, tradition and religious beliefs of those who laid the dead to rest. Someone may have been a warrior in his life, although has no weapons in his grave. Scientists must take great care choosing their study materials, research questions and comparative basis.

Weapons as artefacts are seemingly easy to study. Warfare is a strangely exciting topic to everybody and weapons are a frequent funerary artefact usually giving good background information. Yet we know little about the use of them and the individuals who used them. Some weapons have a unique technique of use, so regular practice can develop unique skeletal traces that we should take advantage of when studying the bioarchaeology and paleopathology of warfare.

The link between some degenerative changes and use of atlatl was already investigated in the 60's (Angel 1966; Ortner 1968). However, there is only one weapon that loads the body from the shoulders to the fingers with the same physical stress as in the case of atlatl - the bow. In the 80's Olivier Dutour suspected a link between some enthesopathies and archery (Dutour 1986), but the great jump in the study of archery-related stress markers was the investigation of the skeletal series of Mary Rose (e. g. Stirland 1991, 1993, 1998; Stirland and Waldron 1997), where the bones of archers using English longbow were examined. Although at the current state of the research we not only have paleopathological data but also the results of sports medicine and kinematics (Squadrone and Rodano 1995; Squadrone et al. 1995; Benjamin et al. 2002), the study of activity-related lesions has more questions than answers yet (Thomas 2014).

In Hungary, some scholars have already targeted enthesopathies of historical series in their research (Józsa et al. 1991, 2004; Józsa and Pap 1996), furthermore, in the case of grave No. 183 from the 10th century AD cemetery of Sárrétudvari Hízóföld (Hajdú-Bihar county, Hungary) György Pálfi and his colleagues suggested a link between some lesions of the elbow and archery (Pálfi et al 1996). However, a systematic research of the activity-related skeletal markers of the Hungarian Conquest Period (10th c. AD) "archers" (individuals buried with archery equipment) is yet to be accomplished.

The lack of systematic Hungarian research is an unfortunate situation, since the Hungarian data could provide a basis for further investigations of activity-related markers even on an international level. According to written sources and archaeological findings, mounted archers were the core of the Hungarian army in the 10th century AD and the bow was a common weapon in that era (Kovács 1986; Révész 1996). However, the identification of archers within the cemeteries remains a major issue. These archaeological and anthropo-

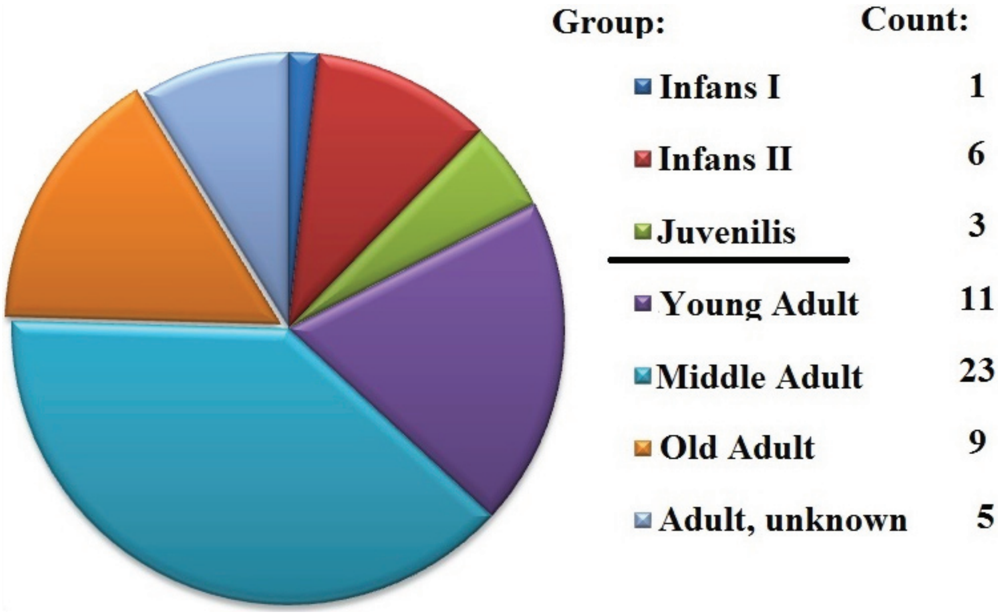

Figure 2. Distribution of the "archers" by age groups.

logical materials are very exciting for both the researchers of this era and those who investigate the archery-related stress markers.

There are no previous Hungarian studies that focus on archery-related changes of a complete skeletal series, to compare our findings with. Accordingly, we must have profound anatomical knowledge on the shooting process, especially on the muscles usually involved, and we must establish some criteria to choose the test-cemetery correctly.

Shooting the bow is a complex anatomical process. According to the literature (Axford 1995; Miltényi 2008), shooting the bow loads the torso and the arms, and a wide scale of muscles are usually involved in the movement, from the shoulders to the fingers (Table 1). Knowing the exact location of these muscles (Fig. 1) we also know which parts of the bones we should be studying in order to find the consecutive entheseal changes that develop on the muscle attachment sites.

The work load of the muscles involved in archery is very different. These muscles lie overlapping each other, some of them do not even attach to the bone surfaces for not all the muscles concerned will have their own observation sites on the bones.

Choosing the test-material, we set up four criteria that a cemetery must pass:

the cemetery must be completely excavated;

both the archaeological and anthropological material must be published;

must contain a great number of male graves

must also contain graves with a great amount of archery-related artefacts.

On the basis of these criteria, we have chosen the 10th AD cemetery of Sárrétudvari Hízóföld. With the biological, anthropological, pathological, archaeological and historical background in mind, in this paper we give a preliminary overview of the activity-induced stress markers of the famous Hungarian human skeletal series. "Archers" and unarmed adult male skeletons are analysed and compared in order to establish a link between skeletal traits and regular activity. Our main intention is to find any specific lesion that can aid the identification of the actual archers of the community.

Materials and Methods

The Hungarian Conquest Period (10th century AD) cemetery of Sárrétudvari Hízóföld and the human skeletal series

The cemetery was excavated between 1983 and 1985 by Ibolya M Nepper. Both anthropological (Oláh 1990; Pálfi 1992; Pálfi 1993; Pálfi et al. 1996) and archaeological (M Nepper 1994; M Nepper 2002) studies have been published from the material. According to them, 262 graves of the total 269 belong to the 10th century part of the cemetery (M Nepper 2002). The 262 graves contained the skeletons of 263 individuals: 162 adults, 98 sub-adults (0-23 yrs) and 3 foetuses

Table 2. Locations of the perceived hypertrophies and entheseal changes.

Code	Characteristic of muscle attachment site
Scapula	
s1:	entheseal changes of the *cavitas glenoidalis*
s2:	hypertrophy of the attachment of *m. subscapularis*
s3:	hypertrophy at the margo lateralis, at the site of the attachment of *m. latissimus dorsi*, *m. teres major*, *m. teres minor* and *m. triceps brachii caput longum*
s4:	non-fusion of the acromion
Clavicula	
c1:	hypertrophy of *ligamentum costoclaviculare*
c2:	hypertrophy of the attachment of *m. deltoideus*
c3:	hypertrophy of the attachment of *m. trapezius*
c4:	hypertrophy of the attachment of *m. subclaviculare*
Humerus	
h1:	hypertrophy of the attachment of the rotator muscles: *m. subscapularis, m. supraspinatus, m. infraspinatus, m. teres minor*
h2:	hypertrophy of the attachment of *m. pectoralis major*
h3:	hypertrophy of the attachment of *m. latissimus dorsi*
h4:	hypertrophy of the attachment of *m. teres major*
h5:	hypertrophy of the attachment of *m. deltoideus*
h6:	*epicondylus medialis* and *lateralis*, *christa supraepicondylaris lateralis* – hypertrophy of the common flexor and extensor muscles
h7:	asymmetry of the *m. biceps* at *sulcus intertubercularis*
h8:	hypertrophy of the attachment of *m. triceps brachii*
h9:	hypertrophy of the attachment of *m. coracobrachialis*
Ulna	
u1:	hypertrophy of the attachment of *m. brachialis*
u2:	hypertrophy of the attachment of *m. supinator*
u3:	hypertrophy of the attachment of *margo interosseus*
u4:	hypertrophy of the attachment of *m. pronator quadratus*
u5:	hypertrophy of the attachment of *m. triceps brachii*
Radius	
r1:	hypertrophy of the attachment of *m. biceps brachii*
r2:	hypertrophy of the attachment of *m. pronator teres*
r3:	hypertrophy of the attachment of *margo interosseus*

(Pálfi et al. 1996). Weapons were found in 58 graves and they appear in every age-group from children to the elderly (Fig. 2). The adults buried with weapons were mostly males, but in grave No. 202 a female was buried with three arrowheads. However, her skeleton was excluded from the current analysis, because the development of activity-induced markers depends on sex too. Beyond weapons, head jewellery, parts of harnesses and knives were often recovered from the graves, but weapons being the only (inorganic) grave good were not uncommon either. The most frequent weapons found in the Sárrétudvari graves were archery-related items: bow (antler bow plates), arrowhead and quiver - each armed grave contained at least one of them. There were also two graves with sabres and one with an axe beyond the archery equipment.

Out of the total 58 “archers”, 49 skeletons were sufficiently preserved to be studied: 9 skeletons out of the total 10 sub-adults and 40 male skeletons out of the total 48 adults. Together with 32 well-preserved skeletons of the total 40 unarmed male individuals, 81 individuals were subjected to macroscopic investigation: the scapulas, the claviculas, the humeruses, the radiuses and the ulnas were thoroughly checked for entheseal changes. Within the “archer” group, entheseal changes of subadults were compared to those of the adult males. Adult male “archers” were also compared with unarmed adult males. No evaluable female remains with archery-related items have been recovered from the site, so adult females were excluded from the investigation. We relied on age at death and sex data of earlier anthropological works on the population (Oláh 1990; Pálfi 1992, 1993; Pálfi et al. 1996) using standard macromorphological estimation methods. Muscle attachment sites were in the focus of the analysis, but we also recorded the traces of traumas and all other pathological changes.

Results and Discussion

We perceived hypertrophy and entheseal changes on a wide scale of muscular attachments (Table 2-3). The fact that different bones naturally have different levels of preservation can distort the general picture of involvement. For example scapulas were the least informative because of their low level of preservation, and we could not make any conclusion based on the data derived from them. If we compare the observed lesions of muscular attachment sites with the muscles usually involved in archery, we can see many similarities. The series of Sárrétudvari contains enough skeletons belonging to the adult age-groups for a detailed statistical analysis in the future, but the preliminary diagrams already give us valuable new information on this issue. It is clear that there are differences between “archers” and unarmed individuals (Fig. 3). However, the locations of hypertrophies are mostly the same in the two groups, and if we compare single “archers” and unarmed individuals, similarities can be tracked down well to the individual level. There are lesions that appear in high frequency in both groups (e. g. hypertrophy of attachments of *m. biceps brachii, m. brachialis*). These common alterations refer to an activity that was widespread among the whole male population regardless of the funerary status of the individual. Thus, investigating the possible traces of archery, only comparing the “archers” with the unarmed individuals is not a sufficient way of examination. However, in the case of the “archer’s” graves, the archaeological and the anthropological data certify each other: most of these people were strong, well trained and muscular, presumably conducting archery-related hard physical activity on a regular base (Fig. 4). Archery related artefacts were not laid in the graves only

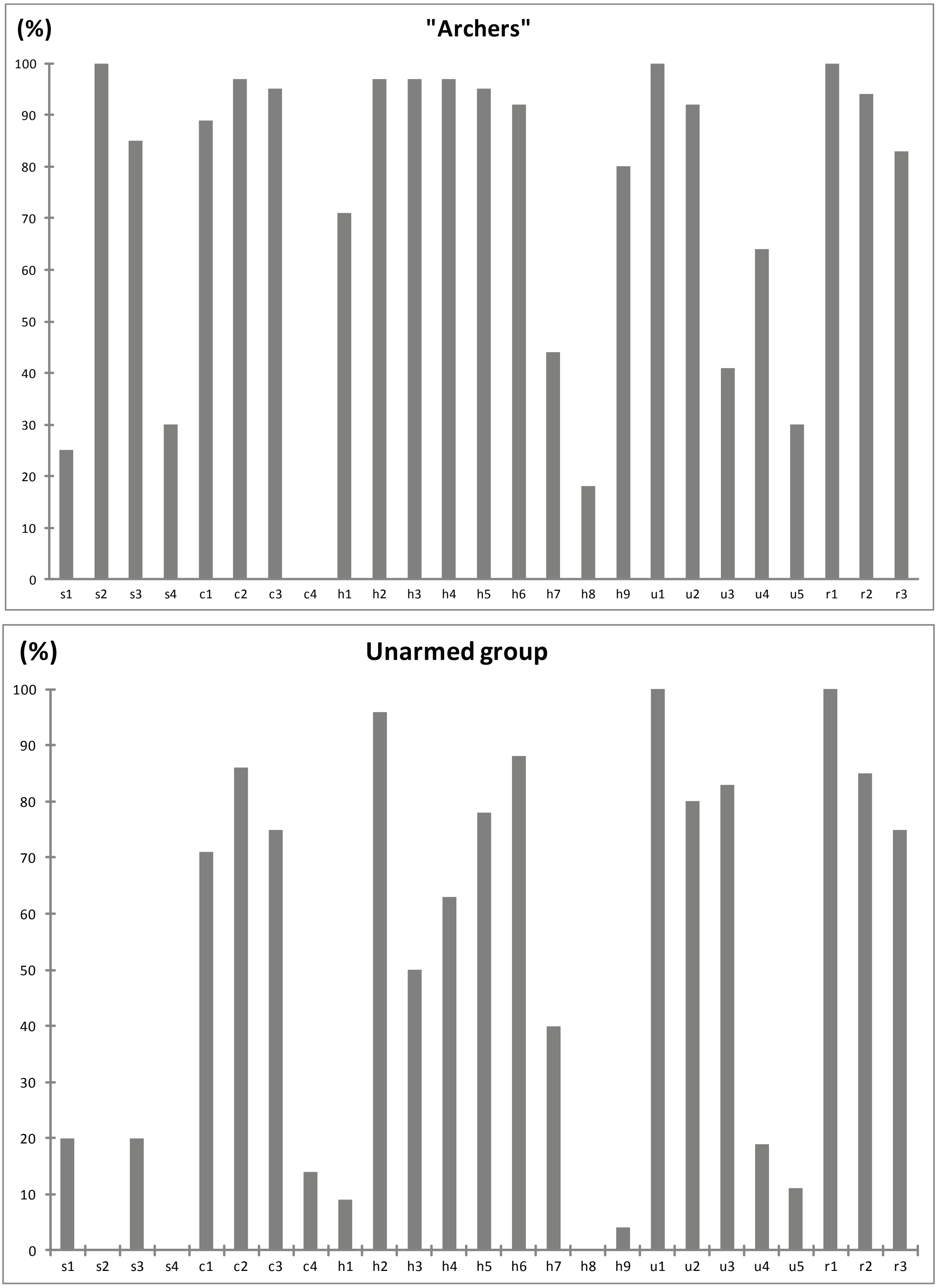

Figure 3. Entheseal changes in the group of the "archers" and the unarmed males. The list of the perceived entheseal changes are detailed in Table 2, the diagram shows their percentage.

Table 3. The anthropological and archaeological data of the analysed individuals. *Could not be analysed* means the skeleton was missing; *Unsuitable for analysis* (*u. a.*) means the level of the preservation is too low; (*?)* means the surface is too eroded at the signed attachement; In case of bilateral involvement, more serious involvement is signed with (*L*) in the left side and (*R*) in the right side.

No. of grave, age-group, state of preservation	Type of weapon	Anthropological data
2. Adult	traces of quiver, arrowheads	Could not be analysed
3. Young Adult well preserved	traces of quiver, bow plates	Scapula: s2, s3; Clavicula: c1, c2, c3; Humerus: h1, h2, h3, h4, h5, h6-?, h7-R, h8; Ulna: u1, u2, u3-?, u4, u5; Radius: r1, r2, r3
5. Middle Adult well preserved fragmented	traces of quiver, 5 arrowheads	Scapula: s2-?, s3; Clavicula: c1, c2, c3; Humerus: h1, h2, h3, h4, h5, h6; Ulna: u1, u2, u3-L, u4; Radius: r1, r2, r3
11. Adult fragmented, eroded	arrowhead	Scapula: s2-?, s3; Clavicula: c1, c2, c3; Humerus: h1, h2, h3, h4, h5; Ulna: u1; Radius: r1, r3, Bilateral healed wrist fracture
15. Old Adult well preserved fragmented	arrowhead	Scapula: s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h2, h3, h4, h5, h6; Ulna: u1, u2; Radius: r1, r2, r3
18. Infans II well preserved fragmented	2 arrowheads	Scapula: u. a.; Clavicula: c2; Humerus: h2; Ulna: u1; Radius: r1
20. Young Adult well preserved fragmented	traces of quiver, 3 arrowheads	Scapula: s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h1, h2, h3, h4, h5, h6, h7-R; Ulna: u1, u2; Radius: r1, r2, r3, Pathological change on the left scapula
21. Middle Adult well preserved fragmented	traces of quiver, 4 arrowheads	Scapula: s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h1-?, h2, h3, h4, h5, h6; Ulna: u1, u2, u4; Radius: r1, r2, r3
24. Infans II well preserved	traces of quiver	Clavicula: c2; Ulna: u1, u2; Radius: r1
29. Old Adult fragmented	traces of quiver, fragments of 7 arrowheads	Scapula: s1, s2-?, s3; Clavicula: c1, c2, c3; Humerus: h1, h2, h3, h4, h5, h6-?; Ulna: u1, u2, u4; Radius: r1, r2, Pathological change on the right elbow
34. Young Adult well preserved fragmented	2 arrowheads	Scapula: s2, s3; Clavicula: c1, c2, c3; Humerus: h1, h2, h3, h4, h5, h6, h7-R; Ulna: u1, u2, u4; Radius: r1, r2, r3
37. Middle Adult well preserved fragmented	2 arrowheads	Scapula: s2-?, s3-?; Clavicula: c2, c3; Humerus: h1, h2, h3, h4, h5, h6; Ulna: u1, u2, u4, u5; Radius: r1, r2, r3
41. Old Adult fragmented, eroded	traces of quiver, 11 arrowheads	Scapula: s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h1, h2, h3, h4, h5, h6; Ulna: u1, u2, u3-?, u4; Radius: r1, r2, r3-?
52. Young Adult fragmented, well preserved	2 arrowheads	Scapula: s1-?, s2-?, s3-?, s4-?; Clavicula: c1; Ulna: u1; Radius: r1 The right shoulder is deformed and shortened
63. Middle Adult fragmented, eroded	traces of quiver, bow plate, arrowhead	Clavicula: u. a.; Scapula: s2?, s3?; Humerus: h2, h3, h4, h5, h6; Ulna: u1, u2, u5; Radius: r1, r2 Traces of Osteoporosis
66. Middle Adult eroded	bow plate, sabre, 2 arrowheads	Scapula: s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h2, h3, h4, h5, h6, h8; Ulna: u1, u2, u3, u5; Radius: r1, r2, r3
71. Middle Adult fragmented	3 arrowheads	Scapula: s2-?, s3; Clavicula: c1, c2, c3; Humerus: h1, h2, h3, h4, h5, h6, h7-R, h8, h9; Ulna: u1, u2, u4, u5; Radius: r1, r2, r3 The left clavicula is fractured and healed abnormally
74. Middle Adult eroded	bow plate, 2 arrowheads	Scapula: s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h1, h2, h3, h4, h5, h6, h7-L; Ulna: u1, u2, u3-?; Radius: r1, r2, r3-?
78. Adult	2 arrowheads	u. a.
80. Middle Adult well preserved	2 bow plates, traces of quiver, arrowhead	Scapula: s2, s3, s4; Clavicula: c1, c2; Humerus: h2, h3, h4, h5, h6; Ulna: u1, u2; Radius: r1, r2, The right clavicula is short, curved and massive
81. Old Adult well preserved fragmented	traces of quiver, arrowhead	Scapula: s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h1, h2, h3, h4, h5, h6; Ulna: u1, u2, u3, u4, u5-?; Radius: r1, r2, r3, Healed fracture on the left clavicula
84. Juvenis fragmented, eroded	4 bow plates, traces of quiver, 3 arrowheads	Scapula, Ulna, Radius: u. a.; Clavicula: c2; Humerus: h5
87. Old Adult fragmented	arrowhead fragment, traces of quiver	Scapula: s1, s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h1, h2, h3, h4, h5, h6; Ulna: u1, u2, u3-?; Radius: r1, r2, r3-? Healed fracture on the left scapula and right clavicula
90. Young Adult fragmented	traces of quiver, fragments of 2 arrowheads	Scapula: s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h1, h2, h3, h4, h5, h6; Ulna: u1, u2, u4; Radius: r1, r2, r3
94. Juvenis fragmented, eroded	bow plate fragments	Scapula, Clavicula: u. a.; Humerus: h2, h3, h4; Ulna: u4; Radius: r1, r2
98. Juvenis fragmented	bow plate, traces of quiver, 4 arrowheads	Scapula, Humerus: u. a.; Clavicula: c1, c2, c3; Ulna: u1; Radius: r1, r3 Traces of infectious disease
106. Middle Adult fragmented	4 bow plates, traces of quiver, 5 arrowheads	Scapula: s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h1, h2, h3, h4, h5, h6; Ulna: u1, u2, u3, u4; Radius: r1, r2, r3
108. Young Adult well preserved	traces of quiver	Scapula: s2, s3; Clavicula: c1, c2, c3; Humerus: h2, h3, h4; Ulna: u1, u4; Radius: r1, r2

Table 3. Continued.

112. Middle Adult fragmented, eroded	traces of quiver, 5 arrowheads	Scapula, Calvicula: u. a.; Humerus: h1, h5, h7-R; Ulna: u1, u2; Radius: r1
123. Adult fragmented, eroded	arrowhead fragment	Scapula: s2-?, s3-?; Clavicula: c2, c3; Humerus: h2, h3, h4, h5, h6; Ulna: u1, u2; Radius: r1, r2-?, r3-?
126. Adult	traces of quiver, 5 arrowheads	u. a.
146. Young Adult eroded	traces of quiver, 4 arrowheads	Clavicula: u. a.; Scapula: s2, s3; Humerus: h1, h2, h3, h4, h5, h6, h7-R, h8-?, h9-?; Ulna: u1, u2, u3-?, u4-?, u5-?; Radius: r1, r2-?, r3-?
158. Infans II fragmented, eroded	arrowhead	Scapula, Humerus, Radius: u. a.; Clavicula: c1; Ulna: u1
160. Middle Adult fragmented	4 arrowheads	Scapula: s1, s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h1, h2, h3, h4, h5, h6, h7-R; Ulna: u1, u2, u4, u5; Radius: r1, r2, r3, Healed fracture on the left clavicula
169. Middle Adult fragmented, eroded	traces of quiver, 3 arrowheads	Scapula: s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h1-?, h2, h3, h4, h5, h6; Ulna: u1, u2, u4, u5; Radius: r1, r2-?, r3-?
171. Middle Adult fragmented, eroded	6 bow plates, 6 arrowheads	Scapula: s2-?, s3; Clavicula: c2, c3; Humerus: h1-?, h2, h3, h4, h5, h6, h7-?; Ulna: u1, u2, u3-?, u4; Radius: r1, r2, r3-?
175. Infans II fragmented, eroded	arrowhead fragment	Scapula: s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h2, h3, h5, h6-?, h7-R; Ulna: u2-?, u3-?, u4-?, u5-?; Radius: r1, r2, r3
178. Old Adult fragmented, eroded	traces of quiver, 5 arrowheads	Scapula: s2-?, s3; Clavicula: c1, c2, c3; Humerus: h1-?, h2, h3, h4, h5, h6; Ulna: u1, u2-?, u3-?, u4-?, u5-?; Radius: r1, r2, r3-?
179. Middle Adult fragmented	2 bow plates, 2 arrowheads	Scapula: s2-?, s3; Clavicula: c1, c2, c3; Humerus: h1, h2, h3, h4, h5, h6, h8; Ulna: u1, u2, u3, u4; Radius: r1, r2, r3
181. Middle Adult well preserved	bow plate	Scapula: s2, s3; Clavicula: c1, c2, c3; Humerus: h1, h2, h3, h4, h5, h6, h7-R; Ulna: u1, u2, u3; Radius: r1, r2, r3
182. Old Adult fragmented, eroded	3 arrowheads	Scapula: s1, s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h1, h2, h3, h4, h5, h6-?, h8; Ulna: u1, u2, u3-?, u4-?, u5-?; Radius: r1, r2, r3 Healed fractures on the right radius and ulna
183. Old Adult fragmented	3 bow plates, traces of quiver, arrowhead	Scapula: s1, s2-?; Clavicula: c2, c3; Humerus: h2, h3, h4, h5, h6, h7-R; Ulna: u1, u2, u3, u4; Radius: r1, r2, r3, Bilateral elbow arthrosis
184. Infans I. fragmented, eroded	arrowhead	Scapula, Radius: u. a.; Clavicula: c1, c2; Humerus: h2, h3; Ulna: u1
185. Old Adult fragmented	3 bow plates and fragments, arrowhead fragments	Scapula: s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h1, h2, h3, h4, h5, h6; Ulna: u1, u2, u4, u5; Radius: r1, r2, r3
197. Young Adult fragmented	traces of quiver, arrowhead	Scapula: s1, s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h2, h3, h4, h5, h6, h7-L; Ulna: u1, u2, u3-?, u4-?, u5-?; Radius: r1, r2, r3-?
206. Middle Adult fragmented	traces of quiver, arrowhead	Scapula: s1, s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h1, h2, h3, h4, h5, h6, h7-L, h9; Ulna: u1, u2, u3, u4, u5; Radius: r1, r2, r3
202. Middle Adult	3 arrowheads	Female
213. Young Adult fragmented, eroded	traces of quiver, 7 arrowheads	Scapula: u. a.; Clavicula: c2, c3; Humerus: h1, h2, h3, h4, h5; Ulna: u1, u2; Radius: r1, r2
214. Middle Adult fragmented, eroded	bow plate fragments, traces of quiver, 4 arrowheads	Scapula, Clavicula, Ulna, Radius: u. a.; Humerus: h1, h2, h3
224. Infans II well preserved	2 arrowheads	Scapula: u. a.; Clavicula: c1, c2, c3; Humerus: h2, h3, h4, h5; Ulna: u1, u2; Radius: r1
232. Middle Adult fragmented	arrowhead	Scapula: s1, s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h1, h2, h3, h4, h5, h6, h7-R, h8, h9; Ulna: u1, u2, u3; Radius: r1, r2, r3
247. Middle Adult fragmented	4 bow plates, traces of quiver, 4 arrowheads	Scapula: s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h1, h2, h3, h4, h5, h6, h8; Ulna: u1, u2, u3, u4-?, u5; Radius: r1, r2, r3
251. Infans II fragmented, eroded	3 bow plates, arrowhead	Scapula, Humerus: u. a.; Clavicula: c1, c2, c3; Ulna: u1; Radius: r1
252. Middle Adult fragmented, eroded	traces of quiver	Ulna, Radius: u. a.; Scapula: s2-?; Clavicula: c1, c2, c3; Humerus: h1, h2, h3, h4, h5, h6, h7-L;
257. Middle Adult fragmented	traces of quiver, 6 arrowheads	Scapula: s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h2, h3, h4, h5, h6, h7-L; Ulna: u1, u2, u3, u4; Radius: r1, r2, r3
258. Young Adult fragmented, eroded	4 bow plates, traces of quiver, 6 arrowheads, axe	Scapula, Clavicula, Humerus, Ulna: u. a.; Radius: r1
259. Middle Adult fragmented, eroded	4 bow plates, 4 arrowheads	Scapula, Clavicula, Humerus: u. a.; Ulna: u1, u2; Radius: r1 Healed fracture on the clavicula
264. Young Adult fragmented	6 bow plates, traces of quiver, arrowhead, sabre	Scapula: s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h1, h2, h3, h4, h5, h6, h7-L; Ulna: u1, u2, u3, u4; Radius: r1, r2, r3
9. Old Adult fragmented, eroded	-	Ulna: u. a.; Scapula: s1, s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h1-?, h2, h3, h4, h6-?; Radius: r1, r2, r3

Table 3. Continued.

14. Young Adult fragmented	-	Scapula: s2-?, s3-?; Clavicula: c2; Humerus: h2, h5, h6; Ulna: u1, u2, u3; Radius: r1, r2, r3
16. Old Adult fragmented, eroded	-	Scapula, Ulna, Radius: u. a.; Clavicula: c1, c2, c4; Humerus: h2, h5
35. Adult fragmented, eroded	-	u. a.
39. Old Adult fragmented	-	Scapula: s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h2, h5, h6; Ulna: u1, u2, u3; Radius: r1, r2
42. Middle Adult	-	u. a.
45. Adult fragmented	-	Scapula: u. a.; Clavicula: c1; Humerus: h2, h3, h4, h5, h6; Ulna: u1, u2; Radius: r1, r2
48. Middle Adult fragmented	-	Scapula: s2-?; Clavicula: c1, c2, c3; Humerus: h2, h6; Ulna: u1, u2, u3, u4; Radius: r1, r3
49. Middle Adult fragmented, eroded	-	Scapula: s2-?, s3; Clavicula: c1, c2, c3; Humerus: h2, h3, h4, h5, h6-?; Ulna: u1, u2; Radius: r1, r2
51. Middle Adult	-	Could not be analysed
62. Middle Adult fragmented	-	Scapula: s2-?; Clavicula: c1, c2, c3; Humerus: h2, h6; Ulna: u1, u2-?, u3, u4; Radius: r1, r3
65. Middle Adult fragmented	-	Scapula: u. a.; Clavicula: c1, c2, c3, c4; Humerus: h1, h2, h3, h4, h5, h6; Ulna: u1, u2, u3; Radius: r1, r2, r3
72. Middle Adult fragmented, eroded	-	Scapula: s2-?; Clavicula: c1, c2, c3; Humerus: h1, h2, h3, h4, h5, h6; Ulna: u1, u3; Radius:r1, r2, r3
79. Adult fragmented, eroded	-	Scapula: s2-?; Clavicula: c2, c3; Humerus: h2, h5, h6; Ulna: u1, u2; Radius: r1, r2
82. Adult fragmented, eroded	-	Scapula, Clavicula: u. a.; Humerus: h1-?, h2, h3, h5, h6-?; Ulna: u1, u2; Radius: r1-?
100. Middle Adult fragmented, eroded	-	Scapula: s1, s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h2-?, h3-?, h4-?, h5, h6; Ulna: u1, u2, u3; Radius: r1, r2, r3-?
105. Middle Adult fragmented	-	Scapula: s1, s2-?, s3-?; Clavicula: c1-L, c2-R, c3-R; Humerus: h2, h3, h4, h5, h6, h7-R; Ulna: u1, u2, u3; Radius: r1, r2, r3
111. Middle Adult	-	u. a.
116. Middle Adult fragmented	-	Scapula: s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h2, h3, h4, h5, h6, h7-R; Ulna: u1, u2, u3; Radius: r1, r2, r3
120. Young Adult	-	u. a.
124. Adult fragmented, eroded	-	Scapula, Clavicula, Humerus: u. a.; Ulna: u1, u2, u3; Radius: r1, r2, r3
125. Middle Adult fragmented, eroded	-	Scapula: s2-?; Clavicula: c1, c2, c3, c4; Humerus: h2, h4, h5, h7-R; Ulna: u1, u2, u3; Radius: r1, r3
128. Young Adult fragmented, eroded	-	Left Humerus, Radius: u. a.; Scapula: s2-?, s3-?;
133. Middle Adult	-	u. a.
145. Middle Adult fragmented	-	Scapula: s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h2, h3, h4, h5, h6; Ulna: u1, u2, u3, u4; Radius: r1, r2, r3
149. Old Adult fragmented	-	Scapula: s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h2, h4, h5, h6, h7-L; Ulna: u1, u2, u3, u4, u5; Radius: r1, r2, r3
172. Middle Adult fragmented	-	Scapula: u.a.; Clavicula: c2-L, c3; Humerus: h2, h3, h5, h7-R; Ulna: u1, u3; Radius: r1, r2, r3
186. Middle Adult fragmented, eroded	-	Scapula: s2-?, s3-?; Clavicula: c1, c2; Humerus: h2, h3, h4, h5, h6-?, h7-R; Ulna: u1, u2, u3; Radius: r1-?, r2, r3-?, Traces of pathological change on the left clavicula
188. Middle Adult fragmented	-	Scapula: s3; Clavicula: c1, c2, c3; Humerus: h2, h4, h5, h6; Ulna: u1, u2, u3; Radius: r1, r2, r3
201. Middle Adult fragmented	-	Scapula: s2-?, s3-?; Clavicula: c1, c2; Humerus: h2, h7-R; Ulna: u1, u2; Radius: r1
218. Middle Adult fragmented	-	Scapula: s2-?; Humerus: h2, h3, h4, h5, h6, h7-R; Ulna: u1, u2, u3; Radius: r1, r2
219. Old Adult fragmented, eroded	-	Scapula s2-?, s3-?, s4-?; Clavicula: c1, c2, c3; Humerus: h1-?, h2-?, h3-?, h4-?, h5, h6; Ulna: u1, u2, u3, u4, u5; Radius: r1, r2, r3
228. Middle Adult fragmented, eroded	-	Scapula: s1, s2-?; Clavicula: c1, c2, c3; Humerus: h2,h4, h5, h6, h7-R; Ulna: u1, u3-?; Radius: r1, r2, r3-?
230. Middle Adult fragmented, eroded	-	Scapula: u. a.; Clavicula: c1, c2, c3, c4; Humerus: h1-?, h2-?, h3-?, h4-?, h5, h6; Ulna:u1, u3; Radius:r1, r2, r3

Table 3. Continued.

231. Middle Adult fragmented	-	Scapula: s1, s2-?; Clavicula: c2, c3; Humerus: h6, h9; Ulna: u1, u2, u3; Radius: r1, r2, r3, Traces of degenerative changes on the right Caput humeri
237. Middle Adult	-	Could not be analysed
242. Young Adult	-	Could not be analysed
243. Middle Adult fragmented	-	Ulna, Radius: u. a.; Scapula: s2-?, s3-?; Clavicula: c1, c2, c3; Humerus: h5;
244. Old Adult fragmented	-	Scapula: s2-?, s3-?; Humerus: h2, h7-L; Ulna: u1, u3; Radius: r1, r2, r3
245. Middle Adult fragmented	-	Scapula: s2-?, s3-?; Clavicula: c2, c3; Humerus: h2, h3, h4, h5, h6; Ulna: u1, u2, u3-?, u5; Radius: r1, r2, r3

for symbolical purposes, although symbolism is definitely one reason of use.

In connection with the “archers” we can say the following:

We found traces of active muscular work even on the bones of sub-adult “archers”. Unfortunately, the small sample size and the eroded surface of the bones did not let us perform more detailed observations, but it seems that some kind of training began during childhood. Also, weapons in toddler’s graves could only play a symbolical role.

Hypertrophies are the dominant lesions observed and although we recorded early-stage degenerative changes, osteoarthrosis is a rare phenomenon (Fig. 5). Heavy workload resulted in degenerative articular changes only exceptionally. It is an important observation for any future investigations concerning the possible strength of the bows.

The observed markers are bilateral, but their severity shows slight asymmetry. Aline Thomas summarized the problem during the interpretation of a French series (Thomas 2014): earlier archery was thought to load the body asymmetrically, so different traces should have been found on the left and the right upper limb. In spite of this, contemporary medical studies proved the two-sided nature of archery. Our material also supports that archery loads both sides of the body.

Hypertrophic sites and entheseal changes that appear in high frequency:

on the clavicle at the attachment of *ligamentum costoclaviculare, m. deltoideus and m. trapezius* AND

on the humerus at the attachment of *m. teres major, m. pectoralis major, m. latissimus dorsi, m. deltoideus* and at the distal end where the common flexors and extensors attach (*epicondylus medialis* and *lateralis* and *crista supraepicondylaris lateralis*) AND

on the radius at the attachment of *m. biceps brachii* and at the site of *margo interosseus* AND

on the ulna at the attachment of *m. brachialis*.

We could record hypertrophy on the forearm at the site of *margo interosseus*. In the same study Thomas concluded that there is no difference between the load of the arm holding the bow and the arm pulling the string (Thomas 2014). However, if we analyse the mechanism of the shooting process, we can recognise one particular region where differences occur between the bow arm and string arm: the fingers. During the shot there is no load on the fingers of the bow arm. But in the string arm the same force loads the fingers as the elbow and the shoulder. It is almost a miracle to have all the phalanges both of the right and left hand recovered in usual excavated materials, fingers are therefore very hard to study, but the anatomy of the human upper limb gives us the opportunity to eliminate this problem. The muscles of the fingers attach on the forearm, mostly on the *membrana interossea*. During the shooting process the flexor muscles of the fingers of the string arms are loaded, so the muscles flex the membrane that can create lesions at the site of its attachment to the radius and ulna (Dósa, personal communication). Furthermore, the muscle of the 1st finger attaches on the membrane closer to the radius, while the other fingers commonly closer to the ulna. Under ideal conditions, there is difference between the lesions occurring with the different shooting techniques (with 1st finger or with the others). But other activities can also affect the fingers, so further investigations are needed for a better interpretation.

Conclusions

Possible skeletal consequences of the Hungarian Conquest Period archery

The investigation of the Sárrétudvari series already gives us many possibilities at the current level of the research. On the basis of the criteria for choosing the test-material, we can already establish a group of possible series to be analysed in the future. In the case of the cemetery of Sárrétudvari the archaeological and anthropological data support each other: the „archers” were well trained and muscular, presumably conducting archery-related hard physical activity on a regular base. „Archer” and „non-archer” graves however must be handled with care, as grave goods (and the lack thereof) do not directly refer to life activities.

It is a great question if we can identify in a series who

Figure 4. Degenerative changes in the series. Activity-induced bilateral osteoarthrosis at the elbows (grave No. 183).

Figure 5. Entheseal changes of affected bones (grave No. 5). The most frequent type of the activity-induced entheseal changes are signed on the claviculas (1. *ligamentum costoclaviculare;* 2. *m deltoideus*), humeruses (1. *m teres major;* 2. *m latissimus dorsi;* 3. *m pectoralis major*), radiuses (*m biceps brachii*) and ulnas (*m brachialis*)

practiced archery regularly. The target of the future research must be to find adequate clues for the diagnoses, but the current list of typical alterations including sites on the clavicles, the humeruses, the radiuses and the ulnas is already a helpful tool in this decision.

There are similarities between the hypertrophy-patterns of "archers" and unarmed individuals. This fact may imply two explanations: first, there could be more "archers" in the cemetery, but their graves did not contain any related artefacts (or they perished). Second, some entheseal changes are not specific enough. Both suggestions need more investigation.

Clearly, there is lot of work to be done in the future. The most urgent task is the microstructural analysis of the entheseal changes on the skeletons of the Hungarian Conquest Period archers, because micro CT analysis can give us precise diagnostics (Berthon et al. 2015). We must make a step forward and complete our macroscopic data with metrical analysis so we can refine our opinions on the macromorphology of the lesions. Examination of other series is needed to extend our database. Comparative analyses will give us the most usable information for which there are two possible future ways: comparison with a known historical material (such as medieval English archers) and examination of contemporary sport archers with medical, radiological and kinetic methods.

The complex investigation of Hungarian Conquest Period archers gives us the chance not just to identify them, but to get closer to the technical questions of the usual movements of archery. At the current level of the investigation we can identify the archers on the basis of the archaeological context and the activity-induced skeletal markers, but further investigation of the Hungarian Conquest Period material is necessary for a better understanding of bioarchaeology of archery.

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