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Paleopathological and radiological examination of the Avar period horse bones from central Balkans (Serbia)

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Summary

During archaeological excavations in September 2009, on the late antiquity necropolis near Obrenovac (Serbia) a horseman's grave, with horse included, was discovered and assigned to the Avar period (the 8th century AD). Horse bones were subjected to pathomorphological and radiological investigations. In order to obtain information concerning equine pathology during Avar domination, 29 bones with changes observed, i.e. in the thoracic and lumbar vertebrae, metacarpal and metatarsal bones and proximal and distal phalanges limbs have been evaluated. Pathomorphology revealed chronic deformative spondyloarthropathy of the spine and ossification of the interosseous ligament both in the metacarpus and in metatarsus, while chronic periostitis was observed in the proximal phalanges, as well as ungular cartilage ossification in all distal phalanges. Based on the pathological findings on the horse's bones, it was concluded that the animal was intensively used for riding and/or as a draught animal during its lifetime, even prior to the completion of its full growth. The pathology revealed on the limb bones indicated long-lasting exposure to the trauma, suggesting that the horse had been probably ridden for long distances on hard, rocky and uneven terrain. It was also concluded that there had been a strong possibility that the mentioned Avar horse had shown symptoms of locomotor disorders due to back pain.

Keywords: paleopathology, paleoradiology, horse, spine, Late Avar period, Serbia

Paleopathological elaborations of animal remains from archeological sites can reveal diseases of the ancient period and are a particularly important source of knowledge about the history of diseases, which is useful for medicine, veterinary medicine, archeology, archaeozoology, etc. The paleopathological evaluations are aimed at understanding the codependence of humans and animals over the course of the time (19, 38). In scientific publications, paleopathology of animals is predominately focused on equides (38). Nevertheless, the data concerning studies of the whole skeletons are exceptional (35), due to the rare finding of entire preserved skeletons. However, pathological changes on the spine (6, 22, 29-32), metacarpal and metatarsal bones (6, 34), or the changes on tibia, talus, calcaneus, tarsal and metatarsal bones (21, 34) have been reported. The data from the literature describing the pathology of the ancient horses is rare. Rooney (38) described changes such as purulent periostitis, osteophytosis, ankylosis, while Dzierzecka et al. (18) noted deformative arthropathy and ankylosis of tarsal joints in horses dating back to the Middle Ages. In England, Bendrey et al. (7) documented the severe inflammatory changes in the ribs, vertebrae and pelvis. A typical inflammatory reaction of equine bones (*periostitis*) from the Roman period was described by

Janeczek et al. (21). Radiological techniques play an important role in the veterinary diagnosis of skeletal pathological changes. Paleoradiological examination uses criteria which are applied in living animals, although archaeological material can undergo some taphonomic factors, which additionally complicate the diagnostic process (10).

There is no doubt that mastering horses had a significant impact on behavioral change and the cultural development of human populations. The horse (*Equus caballus*) certainly used to play an important role among domesticated animals in history. Horses were domesticated much later than Neolithic species (cattle, sheep, goats, pigs *etc.*), and were primarily used in nutrition during the late Neolith in the area of the Eurasian steppes. However, from the moment of equine domestication, humans revealed the art of mastering, training and using horses, which led to revolutionary changes in warfare and transport. It caused the rapid expansion of the nomadic populations of the Eurasian steppe areas throughout Europe and Asia (8, 13).

In 567 AD the Avar tribes appeared in Europe and ruled the entire Pannonian Plain until the beginning of the 9th century, with a short interlude in the middle of the 7th century (27). Considering their nomadic manner of living, Avar stock herding was based on raising large herds of horses in the vast steppes of Eurasia. The Pannonian Plain was a fertile ground for their living habits. The Avar tradition of burying the horse with the dead horseman enabled the exploration of the entire skeletons throughout Hungary, Austria and Slovakia. Most of these horses were stallions or geldings, with the average wither height of 135 cm (3). The analyses of Avar horses were mainly aimed at morphometric, sex and age descriptions. The analyses of pathological changes were to a considerably larger extent carried out on the skeletal remains from Eurasian steppes dating back to the late Neolith, Eneolith and Bronze Age, and have been performed in order to discern the initial steps of secondary utilization, since pathological changes can indicate the manner of exploitation of the horse for riding and pulling (11, 29-32). Changes caused by rider or cargo carrying had been described in 30% of clinically healthy horses (23), and have also been detected in the skeletal remains of an extinct horse, the *Equus occidentalis* (26).

This paper represents an interdisciplinary approach to paleopathological changes observed in the skeleton of a horse from the Avar period. The aim of the evaluation was to reconstruct the possible ethiology, pathogenesis, possible clinical manifestations and the case history of the disease that led to the bone pathology.

Material and methods

The whole remnant skeleton of one horse excavated from an Avar grave of a horseman was analyzed paleopathologically and radiographically according to references (2, 4, 41). Sex was determined on the basis of the pelvis morphology (40). Height at withers was calculated using a modified Kiesewalter method after Johnstone (24). The age of the horse was determined on the basis of dentition morphology. The species identification was based on the visual comparative method using the comparative bone collection of the Laboratory of Bioarcheology, Faculty of Philosophy at the University of Belgrade. All bones identified during the archaeozoological analysis of the bones were included in the pathological evaluation. X-ray analyses of pathomorphologically changed vertebra, metacarpal and metatarsal bones were carried out by Gierth EX9025V camera on Scanx14 phosphorescent plates and Protec 35 X 43 flexible plates. The applied exposure was 50 kV and 6-8 mAs. The morphological changes were estimated with "Reyid" digital caliper with 0.01 mm precision. The grading of interosseal ligament ossification in metacarpal and metatarsal bones was performed according to Bendry (7).

Results and discussion

During the archaeological excavations in September 2009 on the late antique necropolis Ušće near Obrenovac a grave of a horseman was identified (Fig. 1). Judging upon the specific funeral rituals and the archaeological findings using indirect chronology (the horseman's belt and the horse gear), it was stated that grave No 7 dates back to the 8th century AD, the period of the Second Avar Khanat (33). The horse remains were placed on the right side of the horseman, with legs bent under its body and head towards the

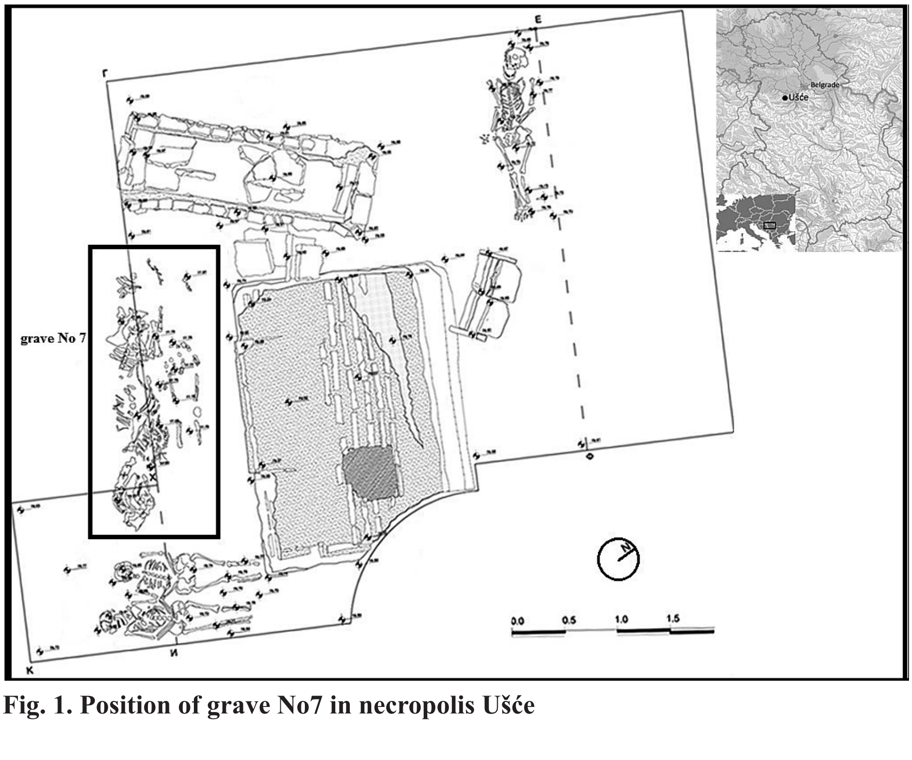

Fig. 1. Position of grave No7 in necropolis Ušće

Fig. 2. Horse skeleton *in situ* (after Marković 2013: 277, fig. 1)

chest, typically for the tombs from the period of Avar domination in Pannonia (Fig. 2) (25, 27). The artifacts belonged to a stallion, 7- or 8-years-old, and the wither height was approximated at 139.7 cm. The proportions and stature of the animal established on the skeletal dimensions were within the range determined for the horse population in the Pannonian Plane during Avar domination (8).

Although the entire equine was excavated, some changes of the discovered skeleton occurred due to post depositional processes, such as settling of the soil after the decomposition of the soft tissue and the changes in pH value of the sediment. Therefore, the best preserved bones were included in the evaluation presented in this paper. The palaeopathological analysis of the Avar horse skeleton proved the preservation of 29 equine bones: one partially fragmented thoracic vertebra within the range from Th7 to Th12, preserved corpuses of Th13 and Th14, almost entirely preserved Th17-Th18, changed lumbar vertebrae L1-L4, left and right metacarpal, left and right metatarsal bones, and proximal and distal phalanges of front and hind limbs.

Pathological changes observed in the thoracic and lumbar vertebrae were proliferative in character. The osteophytes were obvious in the fragmented thoracic vertebra in the range of Th7-Th12. Osteophytes on the vertebral bodies were observed on Th13 and Th14 (Fig. 3). These spurs with a base on the ventral vertebral surface, near the cranial and caudal vertebral extremity protruding into the intervertebral spaces, were 7.5 mm long and 6.5 mm wide, and represented the onset phase of chronic deformative ankylosis: *spondylosis deformans chronica et ankylopoetica*. Ossification was also presented on caudal articulation surfaces (*foveae costales caudales*) of Th17. Intensive bone proliferations (exostosis) that were observed on cranial and caudal articulation processes from L1 to L4 had resulted in vertebral fusion and lateral ankylosis (*spondylosis deformans chronica et ankylopoetica*).

Fig. 3. Caudal surface of T14 with osteophyte (arrow)

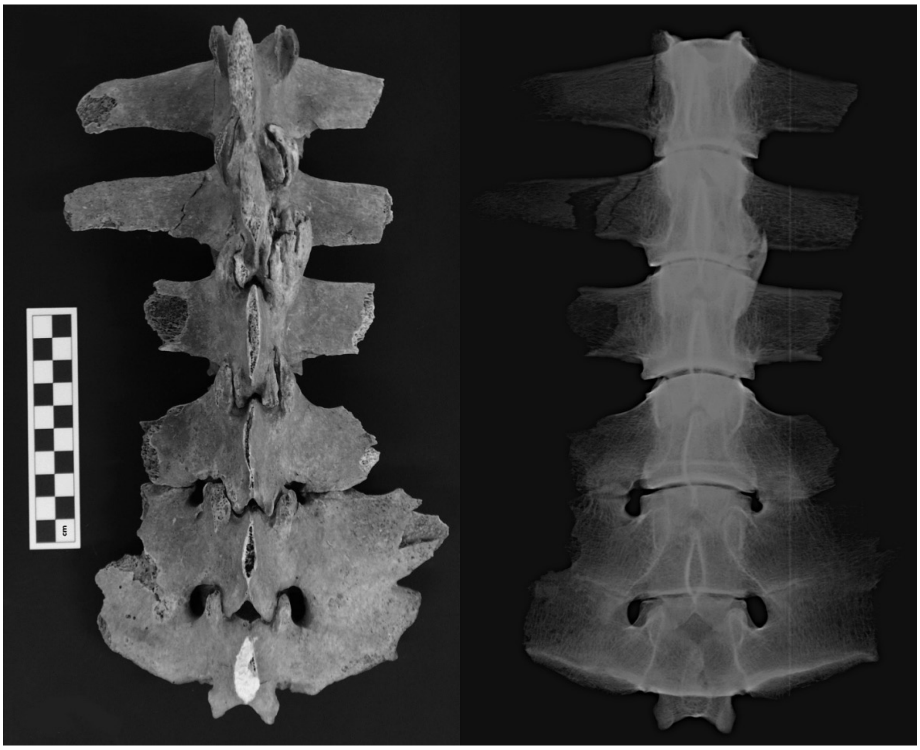

Fig. 4. Photograph (left) and Radiograph (right) of dorsoventral aspect of lumbar vertebrae 1-4 with *corporal spondylosis chronica deformans et ancylopoetica*

The observed intertransversal ankylosis of the L5-L6 cannot be considered as a pathological change, since it is normally found in healthy horses (20), and can be hardly associated with equine pathology. No osteophyte formation was observed on ventral vertebral surfaces of the remnant lumbar spine. Spine radiology revealed advanced lateral ankylosing spondylitis with severe deformities and subchondral sclerosis, together with periarticular syndesmophytes on the second lumbar vertebra. The outlined edges and condensation or turbidity of the corresponding articulation surfaces in the first, second and third lumbar vertebral joints were revealed on the dorsoventral radiographic projection of the lumbar spine (Fig. 3). Additionally, the latero-lateral projection of the cranioventral and caudo ventral stubs of the penultimate and ultimate vertebrae revealed impairments of bone mass, cortical discontinuity and bone rarefaction, proving trabecular damage. Pathological changes were observed both in the metacarpal and metatarsal bones. Due to the ossification of the interosseous ligament, a complete fusion of the metacarpal bones along the diaphysis was clearly visible.

On the metatarsal bones, ossification was revealed on the proximal third of the central tarsal bone. The metacarpal bones Mc II and Mc IV (the splint bones) have fused with the cannon bone (Mc III) (Fig. 5), while proliferations were noticed on the metatarsal bones Mt II and Mt III, whereas Mt IV has not been affected by the process. The changes observed on interosseous ligament (*desmoiditis ossificans ligamentum interosseum ossa metacarpalia et metatarsalia*) on metacarpal and metatarsal bones, were scored upon the intensity of ossification and classified due to the changes observed in the interosseus ligament. The pathological lesions were observed within the 2nd grade according to Bendry (7). Pathological changes in form of exostoses, sequential to the ossification of collateral ligaments insertion points (Fig. 6) were revealed on the proximal phalanges (the long pastern bone) both in the thoracic and in the pelvic limb. The chronic ossifying periostitis was also confirmed by radiology. Radiographic images of the metacarpal and metatarsal bones showed reduced transparency reflected in shadows within bone tissue between the metacarpal and also between the metatarsal bones. Local depositions of calcium salts in the form of homogenous layers were identified in the palmar surfaces of metacarpal and plantar of the metatarsal bones. All the distal phalanges (the coffin bones) showed ossification of cartilages (Fig. 7). Pathological bony spurs up to 35.5 mm wide are predominantly present on the lateral coffin cartilages. The cartilage ossification is more developed on the thoracic proximal phalanges (*ossifi-*

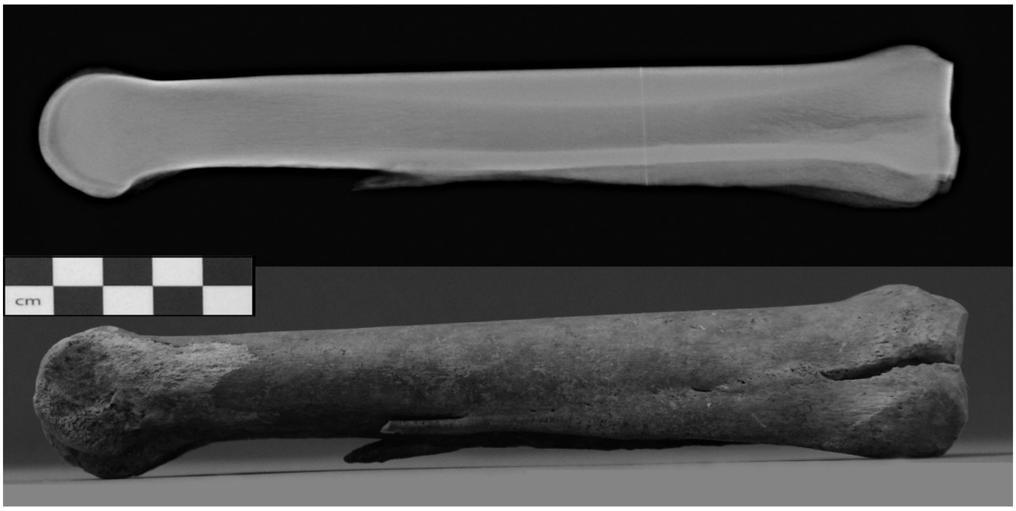

Fig. 5. Photograph (above) and radiograph (below) of right metacarpus in laterolateral position showing *desmoiditis ossificans ligamentum interosseum ossium metacarpalium dexter*

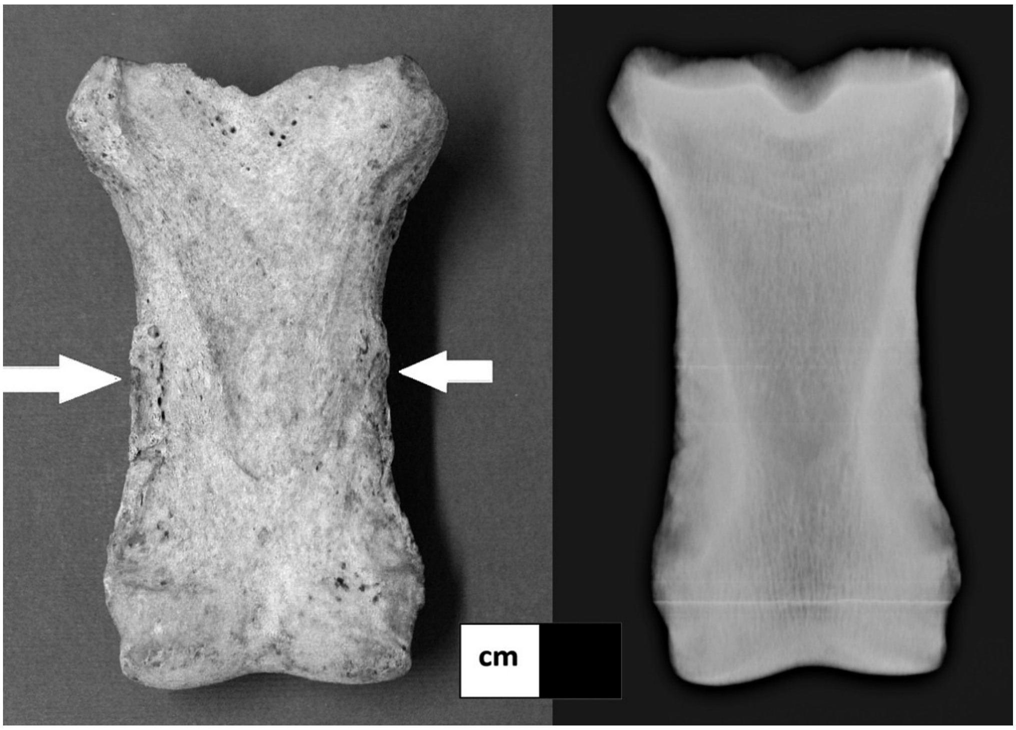

Fig. 6. Photograph and radiograph of the right front (left) proximal phalanges with *periostitis chronica ossificans* (arrow)

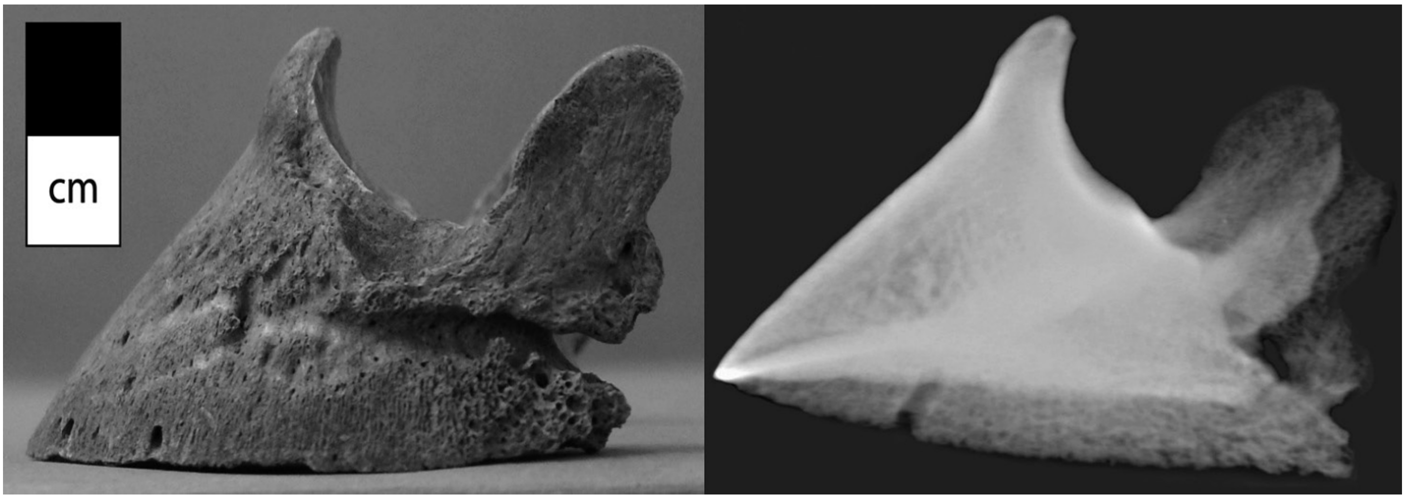

Fig. 7. Photograph (left) and lateromedial radiographic view (right) showing *ossificatio cartilaginis ungulae*

catio cartilaginis ungulae). Radiology revealed unilateral or bilateral proximal ossification of the lateral margins in the cartilage stretching along the angular processes on distal phalanges. Bone proliferations observed vary in length, some of them exceeding the level of the navicular bone, protruding towards the distal interphalangeal joint (coffin joint), thus indicating that the process of ossification lasted longer than 6 months.

The horse remains evaluated in these investigations had no bone fractures, although some cases of multiple fractures and osteomyelitis have been reported finding taking place in similar circumstances (1). Nevertheless, although the changes in the examined bones had shown mild degenerative changes within the joint surfaces, no signs of significant bone lesions, which could represent the cause of the infection, were determined. Numerous pathological changes within equine skeletons have been described in the accessible literature (7, 18, 21, 38). The difference in pathological finding between the bones described in this paper and those determined by Janeczek et al. (21) and Bendrey et al. (7) was that we could not confirm signs of any infection and any septic process occurring in Avar horse. The most significant pathology observed in our horse was deformative spondylosis, also described by Bartosiewicz and Bartosiewicz (4) and Janeczek et al. (22). The pathogenesis of the observed spondylosis may be based on the initial degenerative changes in the intervertebral disc tissue that occur secondarily to trauma (41). The signs of deformative spondylosis observed in fragmented vertebra within the range of Th7-Th12, osteophytes in Th13 and Th14 and ossification masses on the caudal articulation surfaces of Th17-Th18, together with fusion of vertebra within the range L1-L4 were described in the spine of the investigated Avar horse. It was stated that spondylosis most commonly affects equine vertebrae between Th10-Th14 (16). The fusion of the vertebral bodies of Th11 and Th12 and ankylotic changes of the Th14-Th15, as well as bilateral fusion of the vertebral arcs (Th15-L2) and intervertebral calcification from Th12 to L2 were also described by Janeczek et al. (22) in a Medieval horse from Wroclaw, while Bartosiewicz and Bartosiewicz (5) observed spondylosis and the fusion of the thoracic and lumbar vertebrae forming a spinal block in the horse from the Germanic grave. According to Plusowski et al. (36) and Janeczek et al. (22) the possible cause of spondylosis in a horse was intensive labour, such as riding and draugth animal use. Janeczek et al. (22) considered that animals with such pathological changes had been ridden before the body growth was completed, while the load on the back induced increased elongation and traction of the spine.

According to the adopted biomechanical model of horse movement, the equine thoracolumbar spine is a "composite arch", while ligaments and muscles, including the muscles of the abdomen, form a "chord" springing and throwing the body (20). Therefore the pathological changes in the locomotor system can develop for a long period of time without clinical manifestations. The complete biomechanics implies that the spine of the riding horse is relatively rigid and does not bend to the side while moving, which allows the muscles of croup and thighs to perform a strong contraction of the body, that moves upward and forward. Therefore, symmetrical intertransversal ankylosis, similar to our findings, can occur normally in horses. It is believed that muscular activity and pain play a crucial role in the thoracic and lumbar spine pathology in horses and in humans (22, 28). The complete bone fusion of the lumbar spine reduces the joint movements without a serious effect on the mobility of horses (37), and obviously riding is one of the main causes of the vertebral fusion in horses. Also, the saddle type and inappropriate saddling can lead to variations of the spondylosis from mild to severe (6, 29-32).

During the Avar period a saddle with wooden frames (Bartosiewicz and Bartosiewicz (5)) putting pressure on ribs and liberating spinal processes from weight was used (29-32). Avar saddling reduced the risk of injury caused by the crushing of spinal processes in sport and recreational horses as described by Henson (20). Considering the spondyloarthropaty in the thoracic and lumbar spine which was revealed in the investigated animal remains, there was a strong possibility that the horse in our case had long-lasting back pain problems. "Back pain" in horses is a serious diagnostic and therapeutic problem (17) closely associated with the changes in the thoracic, lumbar and sacral spine. Clinical manifestations vary with the degree of neuromuscular dysfunction leading to a frequent decrease of locomotion capabilities and the appearance of lameness (22). It was noted that the spondylosis was mostly expressed in the lumbar (L1-L4) spine of the horse from grave No 7, which can be considered as a "cavalry horse". Apparently, military campaigning predisposed the great stress on the thoracic and lumbar spine, including vertebrae, ligaments and muscles, and this led to chronic inflammatory changes of the ligaments connecting articulation processes. Probably the exploitation of the animal continued so that the chronic process within the spine developed together with the organization and reparatory processes progressed, eventually manifested as the obvious periosteal bone proliferation and the spondylosis.

The ossification of interosseuos ligaments of the metacarpal and metatarsal regions observed in our evaluation was determined both pathomorphologically and radiologically on accessible metacarpal and metatarsal bones. The process was more intense on both the metacarpal than on the metatarsal bones. There are many possible causes of these pathological changes, like trauma and/or labour on hard surfaces, as well as conformational faults contributing to the process. Ossification is the result of friction between periosteums of the metacarpal and or the metatarsal bones (6). Daugnora and Thomas (15) indicated this pathological change occurs more frequently in the metacarpal than in the metatarsal bones because of the greater biomechanical load. Dystrophic calcifications are in the majority cases the result of reduced tissue vitality, local tissue degeneration or inflammatory processes, occurring due to stress and aging. Metacarpal and metatarsal ossification was described as the most frequent finding in 280 horse skeletons from Lithuania (15). This pathological condition – "splints" (metacarpal/metatarsal exostoses or *desmoiditis ossificans chronica*) – can be caused by various external factors (9).

Osteophytes caused by ossification of the collateral ligaments insertions were clearly identified at all proximal phalanges. Similar changes are described by Rooney (38), while Thompson (41) suggests that chronic ossifying periostitis can develop as a result of organism reaction due to some traumas, so it is local and non-infectious in character. This condition is also called "ringbone" (41).

All distal phalanx cartilages in our evaluation were affected by ossification, i.e. "sidebones", with possible causative factors not clearly defined (14). The theories concerning the etiology of *ossificatio cartilaginis ungulae* (sidebone) include hereditary predispositions, trauma or concussion of the hooves, bad shoeing and hoof imbalance (39). Asymmetric calcifications observed also show that the strain and stress predisposed along the stronger ossification side of the distal phalanges was increased during the life of the horse. Since Avar horses were not shoed (27) we can exclude bad shoeing as an etiological factor impacting the development of the distal phalanx cartilage ossification in this horse. However, horses with ossified hoof cartilage do not always show signs of lameness (12) and that was possible in our ancient animal.

Pathologic examination of the Avar horse bones led to considering that the horse mounting and riding, which predisposed back overloading before complete ossification of the young animal skeleton before the age of four years. Osteopathological changes in the bones of all four extremities speak for the intensive exploitation of the horse on hard, rocky and uneven ground. Based on the archaeological context of the skeleton finding of the horse from grave No 7, it was concluded that the animal was used as "cavalry horse" in war campaigns. Pathological findings within the limb skeleton was a factor leading to possible improper burden and transfer of contraction in the lumbar and sacral spine, and promoting the progression of pathological process in the back. Changes in the last thoracic and first lumbar vertebrae are often observed in riding horses and can be a result of inadequate saddling and riding. The pathological changes observed in the skeleton of the Avar horse could trigger back pain, consequent lameness episodes and the refusal of obedience in certain movements, especially during the mounting on the horse.

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