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Vertebral Pathologies in Two Early Modern Period (16th–19th Century) Populations From Croatia

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KEY WORDS bioarchaeology; vertebral pathologies; degenerative joints disease; activity-related stress

ABSTRACT In order to test to what degree Schmorl's nodes (SN), osteophytosis of the vertebral bodies (VO), and osteoarthritis of the articular facets (OA) are useful indicators of activity-related stress, an analysis of their frequencies and severity of expression was conducted in two early Modern period skeletal samples from Croatia—Koprivno and Sisak. Historic and contemporary ethnographic sources suggest that living conditions were more demanding in Koprivno, and that a sexual division of labor existed in both populations. A total of 2,552 vertebral bodies (990 from Koprivno and 1,562 from Sisak) and 5,186 articular facets (2,135 from Koprivno and 3,051 from Sisak) were analyzed. Koprivno exhibits significantly higher total frequencies of SN, VO, and OA than Sisak, and the total frequencies of SN and OA in both series are significantly higher in males. When, however, the series were analyzed by age and sex categories, the same trend was noted only in SN. The frequencies and severity of VO and OA could not be interpreted in keeping with the historic and contemporary ethnographic sources and were additionally, unlike SN, found to be strongly correlated with increased age. This study, therefore, suggests that while SN are useful indicators of different lifestyles and/or different activity patterns between various archaeological populations, VO and OA are—possibly because of their more varied etiologies—less useful markers of activity-related stress. Am J Phys Anthropol 145:270–281, 2011.

Pathological changes in the vertebral column are, together with bone trauma, dental diseases, and osteological and dental indicators of subadult stress, one of the most studied pathological conditions in archaeological series. The studied changes include the frequencies and patterning of: Schmorl's nodes (SN), osteophytosis of the vertebral bodies (VO), and osteoarthritis of the articular facets (OA) (Merbs, 1983; Saluja et al., 1986; Lovell, 1994; Knüsel et al., 1997; Stirland and Waldron, 1997; Sofaer Derevenski, 2000; Üstündağ, 2008).

Bioarchaeological studies suggest that the occurrence and patterning of SN in archaeological series is dependent on factors such as long-term mechanical loading and trauma (Ortner and Putschar, 1981; Stirland and Waldron, 1997; Jiménez-Brobeil et al., 2010), while modern clinical studies suggest additional causes including congenital or developmental defects of the cartilaginous end plate, various forms of metabolic bone diseases, neoplastic disease, degenerative disc disease, and lesions of unknown origin (Hubbard and Gunn, 1972; Hilton et al., 1976; Smith, 1976; Resnick and Niwayama, 1978; Hansson and Ross, 1983; Kornberg, 1988; McLain and Weinstein, 1990; Yochum et al., 1994; Chandraraj et al., 1998; Hasegawa et al., 2004).

Age, repetitive mechanical loading, and movement, are stressed as the main factors influencing the presence and severity of vertebral osteoarthritis (VO and OA) in archaeological series (Rogers et al., 1987; Knüsel et al., 1997; van der Merwe et al., 2006), while modern clinical research (Spector and MacGregor, 2004) has identified an additional cause—genetic influences.

Although the frequencies and distributions of SN, VO, and OA have been investigated in numerous archaeological series from different parts of the world, many processes related to their development remain unresolved leaving the accumulated data open to different interpretations. Because physical activity is just one of the multiple factors influencing their development (Jurmain, 1999), an issue that remains unresolved is the value that these lesions have as markers of activity-related stress. Consequently, the usefulness of analyzing SN, VO, and OA frequencies and distributions in order to identify different lifestyles and activity patterns—whether between different archaeological series, social groups, or between the sexes, is currently under debate.

Knüsel et al. (1997) argue that there is no clear correlation between the presence of degenerative joint disease (DJD) and physical activity, and that the spine is not a good structure to study markers of occupational stress because of the biological constraints on its function. Bridges (1994) stated that the patterning of vertebral arthritis in various skeletal samples is primarily a result of stresses imposed by spinal curvature and weight-bearing caused by our erect posture, but also suggested that high levels of osteophytosis in the cervical segments of a Native American sample from northwestern Alabama may be a consequence of their use of tumplines when carrying heavy burdens. Similarly, in a study of spinal

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arthritis in the Bronze Age Harappa, Lovell (1994) suggested that the pattern of arthritis in the cervical spine may reflect activity stresses, possibly carrying heavy loads on the top of the head.

Probably the best known analysis of osteoarthritis in human skeletal material is the study Merbs (1983) conducted on Sadlermiut Eskimo skeletons in which he noted distinctive patterns of arthritis that corresponded with specialized activities recorded in ethnographic sources—suggesting, therefore, that osteoarthritis can be used as an activity-related marker. Similarly, while analyzing degenerative bone changes in two medieval/modern period British series—the rural population from Ensay, and the urban population from Wharram Percy–Sofaer Derevenski (2000) noted not only higher levels of osseous changes in Ensay—suggesting that this sample was under more stress than the sample from Wharram Percy, but also different frequencies and distributions of bone changes between males and females in the Ensay sample suggesting sex-related differences in activity patterns in this series (Sofaer Derevenski, 2000). Stirland and Waldron (1997) concluded that degenerative changes recorded in the spines of the crew of the 16th century battleship *Mary Rose* were caused by activities undertaken on board the ship, while Üstündağ (2008) reported that her analysis of the frequency and distribution of SN in an 16th–18th century Austrian series cautiously suggests that SN are a useful indicator of occupational/behavioral stress.

Given the contradictory nature of the evidence accumulated so far, an excellent summation of our current understanding of this problem was given by Larsen (2003, p 164) who observed that "...the linkages between physical activity and osteoarthritis are not straightforward," and "...although articular pathology relating to activity offers important insight into behavioral characteristics of human populations in a general sense, the identification of specific activities or occupations from individual remains may not always be possible."

In this article, we test the hypothesis that SN, VO, and OA are useful indicators of general activity-related stress in archaeological skeletal series. To accomplish this we analyze and compare the frequencies and severity of expression of these pathologies in two temporally congruent Croatian archaeological series with very different lifestyles: Koprivno—a rural community forced to eke out an existence in the rugged Dalmatian karst hinterland, and Sisak—an affluent urban community devoted to commerce, crafts, and administration. Abundant and detailed historical and contemporary ethnographic sources document that while these two communities differed significantly in the level of physical stress that was necessary to survive in them, a feature common to both was a sexual division of labor in which males were responsible for heavy physical labor, while females were responsible for chores related to the household. If, therefore, SN, VO, and OA are reliable indicators of general activity-related stress, we expect greater frequencies of these pathological changes in the Koprivno series, as well as in males from both sites.

MATERIALS AND METHODS

Geographic, historic, and archaeological context

The skeletal material analyzed in this study consists of two early Modern period (16th–19th century) skeletal samples from Croatia: Koprivno and Sisak. Their geographic locations are shown in Figure 1.

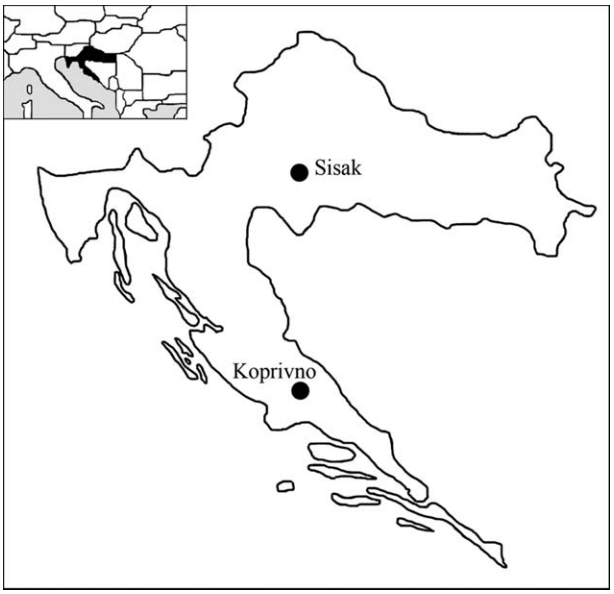

Fig. 1. Map of Croatia with geographical location of Koprivno and Sisak.

Koprivno is located 13 km north of Split in southern Croatia. It is situated in typical Dalmatian hinterland terrain—on the edge of a large field, at an average altitude of 396 m, surrounded by karst hills, separated from the Adriatic Sea by the steep slopes of the Mosor Mountain (Rogošić, 2001). The region is characterized by almost impassable macchia shrubbery and thickets composed of mostly thorny species (Rogošić, 2001). The cemetery was discovered in 2000 during construction of the Zagreb—Split motorway following which a rescue excavation was carried out from 2001 to 2002. The cemetery contained 97 graves. Grave accessories were common, but uniform and modest: parts of clothing (linen and leather), iron needles, buttons, clasps for clothing, and coins. Based on these artifacts, use of the cemetery was dated to the period between the 16th and 18th centuries (Gjurašin, 2005). During this time, the village of Koprivno was inhabited first by Turkish subjects known as Vlachs, and following the expulsion of the Turks in the 17th century, by a Croatian population that migrated to this region from an area in south-western Bosnia and western Herzegovina (Kužić, 2001). The complete skeletal sample consists of 146 individuals: 86 subadults, 33 adult females, and adult 27 males (Novak et al., 2007).

During the early Modern period, Koprivno was a small rural community. The primary occupation of its inhabitants was transhumant pastoralism (Šarić, 2008) with average flocks consisting of between 200 and 600 sheep, along with some large cattle (Jurin-Starčević, 2008). The inhabitants of Koprivno also engaged in an extensive form of agriculture that, because of the use of primitive tools, required a large amount of hard and intensive physical labor (Jurin-Starčević, 2008). Contemporary ethnographic sources state that, as the soil was filled with large rocks and covered in thorny vegetation (Muraj, 2004), this labor was done by men using hacks or pickaxes. Additional burdens to the already large amount of physical stress that the inhabitants of

Koprivno were subjected to were obligations imposed by the Ottoman authorities for free public labor know as *kulluk*. This obligation forced adult males to participate in the construction and maintenance of roads, bridges and forts, as well as the cutting of woods (Jurin-Starčević, 2008).

Sisak is located 55 km south-east of Zagreb in the low flooded area between the Sava, Kupa, and Odra rivers at an average altitude of 98 m. The terrain in this region is characterized by broad river valleys with predominating plough land, pastures, meadows, and woods (Slukan Altić, 2004). Archaeological excavations in the Josip Jelačic Square in the center of modern Sisak carried out from 1997 to 1998 revealed the presence of the main town cemetery with 176 graves whose use was, based on the recovered archaeological artifacts—buttons, belt buckles, rosary beads, medals, and rings—dated to the period between the 17th and 19th centuries (Lolić, 2001). The cemetery was adjacent to the most important town church (the church of the Elevation of the Holy Cross) and was consequently the most prestigious cemetery in the city. The skeletal sample from Sisak consists of 152 skeletons (19 subadults, 62 adult females, 70 adult males, and one unsexed individual).

In marked contrast to Koprivno, Sisak was an affluent urban community that, owing to its favorable geographical position on the southern border of the fertile Pannonian Plain at the confluence of the navigable Sava and Kupa rivers, became one of the most important urban centers in continental Croatia during the early Modern period.

From as early as the 18th century, three annual grain fairs were held in Sisak. This, together with the permanent presence of both a surgeon and an apothecary inside the city walls (Buturac, 1960) attests to the significance Sisak had in 18th century Croatia. During the 18th and 19th centuries, Sisak became the major Croatian center for trade and the transport of grain, timber, and tobacco. Cargo was transported by river boats from the eastern parts of the Habsburg Monarchy to Sisak where it was transshipped into wagons and transported by roads to the northern Adriatic ports of Rijeka and Senj (Slukan Altić, 2004). The increased commerce resulted in Sisak being granted the status of a free market town, and the right to hold a local magistrate court consisting of merchants, craftsmen, and members of other professions (Slukan Altić, 2004). At the same time, the administrative apparatus of the town—the judges, notaries, and various other officials—was significantly enlarged (Buturac, 1960).

Ethnographic data concerning sexual division of labor

While abundant historical and contemporary ethnographic data suggest significantly different lifestyles, with marked differences in the levels of general physical stress, a feature common to both communities was a sexual division of labor. Contemporary ethnographic sources indicate that the following physical activities were performed in Koprivno by men: plowing, hoeing, carpentry, preparation and treatment of hides, cutting firewood, clearing land for vineyards, mowing with scythes, building and maintenance of roads, bridges and forts, loading carts, and transhumant pastoralism (Ivanišević, 1987; Vojnović Traživuk, 2001). Women regularly performed all tasks related with milk and textile processing (milking, production of cheese, washing, screening and wool spinning, weaving and production of clothes, and other textile items), and all activities related to the house and yard: gardening, fetching water, washing and cleaning, cooking, animal feeding, as well as taking care of children (Muraj, 2004; Šestan, 2008).

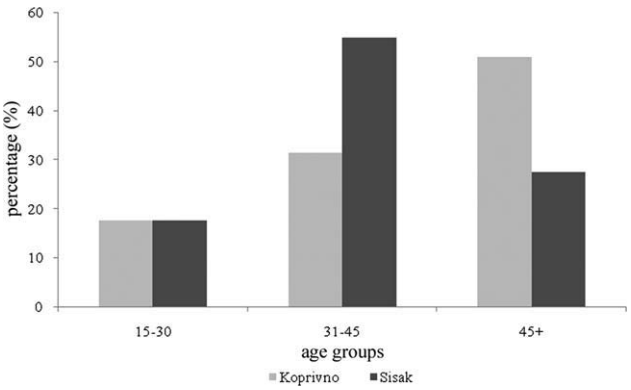

Fig. 2. Age distribution in Koprivno and Sisak.

In Sisak, males were primarily engaged in administration, commerce, professional activities such as doctors and lawyers, and various crafts. There is, of course, the possibility that some individuals were laborers working in the river docks, but it is unlikely that many such individuals would have been buried in the most prestigious town cemetery. Women's responsibilities were limited to chores in and around the house (taking care of domestic animals, gardening, cooking, cleaning and washing, and taking care of children (Lang, 1992).

The Koprivno and Sisak skeletal samples

The analyzed sample from Koprivno consists of 51 skeletons (30 females and 21 males), while the sample from Sisak consists of 91 skeletons (45 females and 46 males). The male/female ratios in both samples are similar ($\chi^2 = 0.807$, $df = 1$, $P = 0.369$), as are the male and female age distributions in each site ($\chi^2 = 4.24$, $df = 2$, $P = 0.121$ in Koprivno; $\chi^2 = 1.56$, $df = 2$, $P = 0.458$ in Sisak). Significant differences are, however, present in the total age distributions recorded in Koprivno and Sisak–Koprivno contains a higher proportion of older individuals: $\chi^2 = 7.852$, $df = 2$, $P = 0.019$ (Fig. 2). Because of this comparison between the series are made by both sex and age categories.

Because of the poor and/or partial preservation of some skeletons in both samples data collected in this analysis are presented by vertebrae. Three types of vertebral pathological changes were studied: SN, VO, and OA. A total of 990 vertebral bodies (588 females and 402 males) from Koprivno and 1,562 vertebral bodies (752 females and 810 males) from Sisak were examined. Additionally, 2,135 articular facets (1,302 females and 833 males) from Koprivno and 3,051 facets (1,459 females and 1,592 males) from Sisak were analyzed.

Description of the analyzed vertebral pathologies

Only adult skeletons (over 15 years of age) were analyzed in this study. The sex of the recovered individuals was determined on the basis of pelvic (Bass, 1995) and cranial (Krogman and Işcan, 1986) morphology. Several factors were used to assess age at death: ectocranial and maxillary suture fusion (Meindl and Lovejoy, 1985;

Fig. 3. Large SN on T7 from Koprivno.

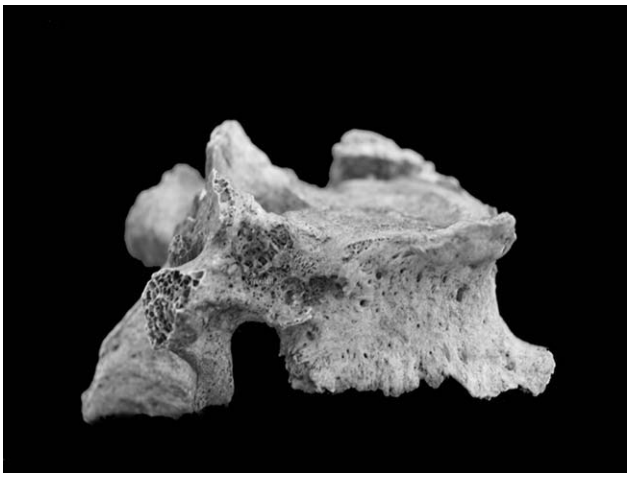

Fig. 4. Moderate VO on T10 from Koprivno.

Mann and Jantz, 1988), pubic symphysis morphology (Brooks and Suchey, 1990), auricular surface morphology (Lovejoy et al., 1985), and changes on the sternal ends of the ribs (Işcan et al., 1984, 1985). Adults were grouped into one of three composite age categories: young (between ages 15 and 30), middle age (between ages 31 and 45), and older (45+ years).

SN are vertical herniations of intervertebral disc tissue into the neighboring vertebral body end plates (Schmorl and Junghanns, 1971). The intervertebral discs consist of a fibrous "capsule" containing a gelatinous internal substance. The constant stress, to which these discs are subject, causes the internal nucleus pulposus to invade the annulus fibrosus. The rupture of this fibrous capsule stimulates the growth of bone called osteophytes from the margins of the vertebral body itself (Roberts and Manchester, 2007, p 139–140). They are recognized morphologically as shallow, round, or kidney-shaped defects with sclerotic margins on the superior or inferior surface of the body of the vertebra (Fig. 3). In the available data set, all thoracic, lumbar, and first sacral vertebral bodies were examined for the presence/absence

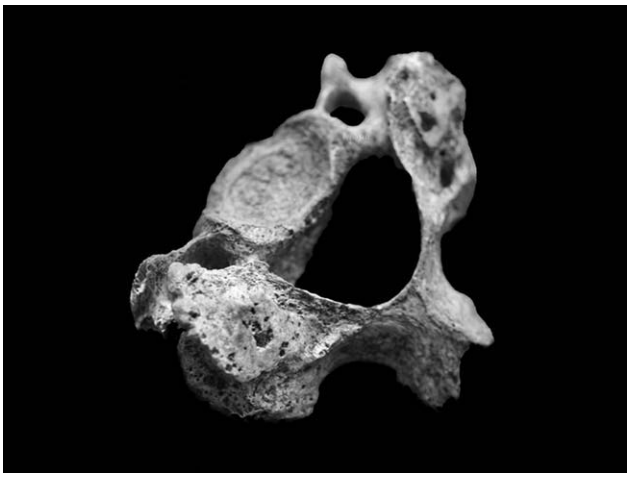

Fig. 5. Severe OA on C4 left superior articular facet from Sisak.

of SN. A total of 782 vertebrae from Koprivno and 1,283 vertebrae from Sisak were examined. In cases when SN were noted on both surfaces of the vertebral body only one SN was taken into consideration for the analysis.

The presence/absence of VO was analyzed on all available cervical (with the exception of the atlas), thoracic, lumbar, and first sacral vertebral bodies. A total of 990 vertebrae from Koprivno and 1,562 vertebrae from Sisak were examined. The scoring system of Lovell (1994), slightly modified by Üstündağ (2008) was used to record VO severity. This system consists of four categories: "none", "slight" (slight marginal lipping), "moderate" (moderate horizontal marginal lipping) (Fig. 4), and "severe" (considerable marginal lipping).

Posterior apophyseal joints of the vertebrae are also affected by joint disease and can exhibit changes such as osteophytes (lipping), pitting, and eburnation. OA was recorded for all joint surfaces present using the Lovell (1994) scoring system, again modified by Üstündağ (2008): "none", "slight" (slight marginal lipping and pitting of 10% of the facet joints), "moderate" (moderate marginal lipping and pitting of 10–50% of the facet joints), and "severe" (considerable marginal lipping and pitting of >50% of the facet joint and/or eburnation) (Fig. 5). If a score was noted for slight lipping on both, for example, T5 inferior articular facets, and at the same time a score for moderate lipping on the superior articular facets of T6, the higher value of these two was taken as the score for the T5/T6 articulation, i.e., moderate lipping was recorded. Left and right sides of each articular facet were scored separately. A total of 2,135 articular facets (left and right side combined) from Koprivno and 3,051 facets from Sisak were analyzed for the possible presence of arthritis.

Data gathered in this study were analyzed using SPSS 14.0 for Windows. The observed differences in the frequencies of vertebral pathologies were evaluated with the χ^2 test using Yates correction when appropriate, and statistical significance was defined by probability levels of $P \leq 0.05$.

RESULTS

The frequency of each type of analyzed vertebral pathology in the analyzed sites is shown in Table 1. The

TABLE 1. Total frequencies of the analyzed vertebral pathologies in Koprivno and Sisak

	Schmorl's nodes	Osteophytosis	Osteoarthritis facets
Koprivno–Kod križa	230/782 (29.4%)	440/990 (44.4%)	1,119/2,135 (52.4%)
Sisak–Sveti Križ	226/1,283 (17.6%)	577/1,562 (36.9%)	1,447/3,051 (47.4%)

total frequencies of SN, VO, and OA are all significantly higher in Koprivno than in Sisak (for SN $\chi^2 = 38.615$, $df = 1$, $P < 0.001$; for VO $\chi^2 = 13.926$, $df = 1$, $P < 0.001$; for OA $\chi^2 = 12.289$, $df = 1$, $P < 0.001$). However, as previously noted, because the Koprivno sample contains a significantly higher proportion of older adult individuals than Sisak, these data require a more detailed analysis.

Schmorl's nodes

The total frequency of SN in the Koprivno sample is 29.4%; in Sisak, it is 17.6%. In the Koprivno sample SN are observed from T3 to S1, while in Sisak they are found from T4 to S1. Differences in SN frequencies between the two series are considerable: the Koprivno sample exhibits a much higher SN frequency in all vertebrae between T5 and L5, with significant differences present in T9, T10, T12, and L1 (range of χ^2 values between 4.316 and 17.868).

The highest frequency of SN in Koprivno is recorded in T12 (71.4%) while in Sisak it is noted in T9 (38.4%) (Fig. 6). In both series, SN are slightly more common in thoracic than in lumbar vertebrae (combined with S1): 31.1% versus 25.8% in the Koprivno series compared to 18.7% versus 15.3% in the Sisak sample. SN frequencies are significantly higher in Koprivno than in Sisak in both thoracic and lumbar regions: for the thoracic region $\chi^2 = 27.611$, $df = 1$, $P < 0.001$; for the lumbar $\chi^2 = 10.351$, $df = 1$, $P = 0.001$.

At the level of the complete spine (Table 2), SN are, in both samples, significantly more common in males than in females (for Koprivno: $\chi^2 = 10.721$, $df = 1$, $P = 0.001$; for Sisak: $\chi^2 = 18.324$, $df = 1$, $P < 0.001$). In both series, males exhibit significantly higher frequencies of SN than females in thoracic vertebrae (for Koprivno: $\chi^2 = 9.951$, $df = 1$, $P = 0.002$; for Sisak: $\chi^2 = 15.62$, $df = 1$, $P < 0.001$). In the lumbar + S1 spine, these differences are not significant. As male and female age distributions are, in both series, similar, comparisons between the sexes can be made at the level of all three analyzed age categories, and at the level of total male and female frequencies. These analyses show that at the level of total thoracic and lumbar vertebrae frequencies, males exhibit higher frequencies of SN than females in five of eight categories: young ($\chi^2 = 4.039$, $df = 1$, $P = 0.044$), middle age ($\chi^2 = 11.233$, $df = 1$, $P < 0.001$), and total adult ($\chi^2 = 10.721$, $df = 1$, $P = 0.001$) frequencies in Koprivno, and middle age ($\chi^2 = 31.931$, $df = 1$, $P < 0.001$) and total adult ($\chi^2 = 18.334$, $df = 1$, $P < 0.001$) frequencies in Sisak.

Analyses between the two sites show higher frequencies of SN in Koprivno for both sexes (for males $\chi^2 = 21.596$, $df = 1$, $P < 0.001$; for females $\chi^2 = 26.054$, $df = 1$, $P < 0.001$). Because, as previously noted, Koprivno contains a significantly higher proportion of older individuals than Sisak, comparisons between the sites need to be made at the level of the three analyzed age categories. These analyses show that Koprivno exhibits significantly higher SN frequencies in four of six categories: young males ($\chi^2 = 12.631$, $df = 1$, $P < 0.001$), middle-aged males ($\chi^2 = 24.747$, $df = 1$, $P < 0.001$), middle-aged females ($\chi^2 = 30.589$, $df = 1$, $P < 0.001$), and old females ($\chi^2 = 13.173$, $df = 1$, $P < 0.001$).

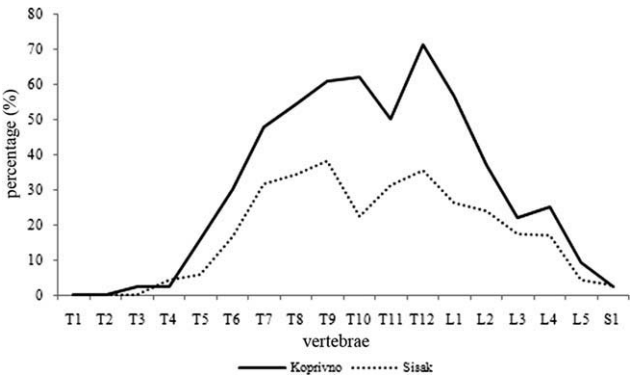

Fig. 6. Total SN frequencies by vertebrae in Koprivno and Sisak.

The distribution patterning between sexes in both samples is similar: in Koprivno, the highest frequency in males is observed in T12 and T10, while in females SN are most common in T12 and T9. In males from Sisak SN are most frequent in T9 and T12, while among females the highest prevalence was observed in T12 and T9 (Fig. 7).

In both series, SN frequencies do not increase with age. In Koprivno, SN frequencies increase from young adults (20.0%) to middle-aged adults (36.8%), then decrease in older adults (27.8%), while in Sisak these frequencies continuously decrease from the younger, through the middle age group to the older age group (21.3%, 17.1%, and 16.0%).

Osteophytosis of the vertebral bodies

VO frequencies are higher in Koprivno than in Sisak in all analyzed vertebral regions. The difference achieves significance in the cervical region ($\chi^2 = 18.635$, $df = 1$, $P < 0.001$), and the same trend, without achieving statistical significance, is noted in both thoracic and lumbar regions. In both samples, a constant increase of VO frequencies through the vertebral regions is noted: lowest values of VO are observed in the cervical region, intermediate values in the thoracic region, while highest values are recorded in the lumbar region (Table 3). VO distribution patterns in both samples are similar: the most commonly affected vertebrae in Koprivno are the C6 in the cervical region, the T4 in the thoracic region, and the L5 in the lumbar region. In Sisak, the highest VO frequencies are recorded in C5, T7, and L5 (Fig. 8).

At the level of the complete spine (cervical, thoracic, and lumbar + S1) males exhibits higher frequencies of VO than females in two of eight categories: in middle age ($\chi^2 = 5.549$, $df = 1$, $P = 0.02$) and total adult frequencies ($\chi^2 = 34.095$, $df = 1$, $P < 0.001$) in Koprivno. Significant differences in VO frequencies between males and females were not recorded in any age categories in Sisak.

Comparisons between the two samples show that Koprivno exhibits significantly higher VO frequencies in

TABLE 2. SN frequencies by vertebral regions, sex, and age categories in Koprivno and Sisak

	Koprivno						Sisak					
	Thoracic		Lumbar + S1		Total		Thoracic		Lumbar + S1		Total	
Sex/age	*n/N*	%	*n/N*	%	*n/N*	%	*n/N*	%	*n/N*	%	*n/N*	%
F 15–30	15/91	16.5	7/41	17.1	22/132	16.7	18/75	24.0	9/23	39.1	27/98	27.6
F 31–45	30/100	30.0	11/48	22.9	41/148	27.7[a]	18/216	8.3	7/99	7.1	25/315	7.9
F 45+	38/130	29.2	16/59	27.1	54/189	28.6[a]	17/116	14.7	6/65	9.2	23/181	12.7
F total	83/321	25.9[a]	34/148	23.0[a]	117/469	24.9[a]	53/407	13.0	22/187	11.8	75/594	12.6
M 15–30	5/7	71.4	1/1	100.0	6/8	75.0[a,b]	15/84	17.9	6/43	14.0	21/127	16.5
M 31–45	39/74	52.7	16/39	41.0	55/113	48.7[a,b]	71/284	25.0	30/135	22.2	101/419	24.1[b]
M 45+	38/128	29.7	14/64	21.9	52/192	27.1	23/91	25.3	6/52	11.5	29/143	20.3
M total	82/209	39.2[a,b]	31/104	29.8	113/313	36.1[a,b]	109/459	23.7[b]	42/230	18.3	151/689	21.9[b]
Total	165/530	31.1[a]	65/252	25.8[a]	230/782	29.4[a]	162/866	18.7	64/417	15.3	226/1,283	17.6

n = number of vertebral bodies exhibiting Schmorl's nodes; *N* = number of examined vertebral bodies; % = percentage of vertebral bodies exhibiting Schmorl's nodes.
[a] Significant differences between samples (total values only).
[b] Significant differences between sexes within a sample (total values only).

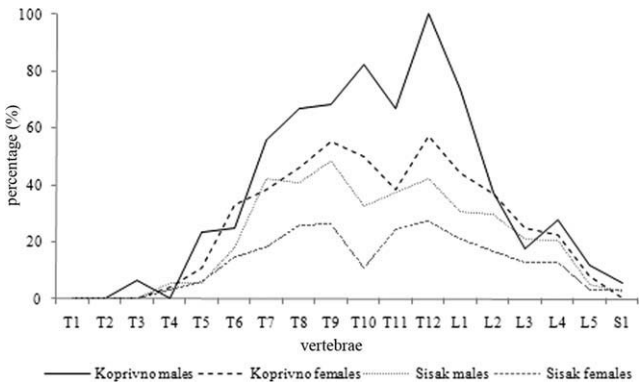

Fig. 7. SN frequencies by sex in Koprivno and Sisak.

older females ($\chi^2 = 3.914$, $df = 1$, $P = 0.048$), while Sisak exhibits higher frequencies of VO in middle-aged females ($\chi^2 = 4.682$, $df = 1$, $P = 0.03$).

The VO distribution patterning by vertebrae between the sexes in the Koprivno sample is similar (with continuously higher frequencies in males), while the patterning between males in females in the Sisak sample is almost identical (Fig. 9).

At the level of total samples, VO severity frequencies adhere to the same pattern in both series with the most common manifestation of VO being slight, followed by moderate and severe (Table 4). The same pattern is noted in all three analyzed spinal regions. In both series, VO is least severe in the thoracic region.

Analyses by sex show that both samples exhibit the same pattern of VO severity in males and females. The most common manifestation of VO in both sexes is slight, followed by moderate and severe. Males exhibit significantly more severe VO than females in four of eight analyzed categories: in older ($\chi^2 = 7.058$, $df = 2$, $P = 0.03$) and total adult ($\chi^2 = 9.466$, $df = 2$, $P = 0.009$) categories in Koprivno, and in middle age ($\chi^2 = 15.048$, $df = 2$, $P < 0.001$) and total adult ($\chi^2 = 7.74$, $df = 2$, $P = 0.02$) categories in Sisak.

At the level of total samples, VO is significantly more severe in the Koprivno series ($\chi^2 = 6.989$, $df = 2$, $P = 0.03$). When, however, the samples are analyzed by age and sex, no significant differences are noted in any of the six available categories.

In contrast to the trend noted in SN, both series exhibit a strong positive association between higher VO frequencies and older age categories (for Koprivno: $\chi^2 = 286.428$, $df = 2$, $P < 0.001$; for Sisak: $\chi^2 = 273.027$, $df = 2$, $P < 0.001$).

Osteoarthritis of vertebral articular facets

The total OA frequency (left and right sides combined) is significantly higher in Koprivno than in Sisak ($\chi^2 = 12.288$, $df = 1$, $P < 0.001$) (Table 5). In both series, the frequency is slightly higher on the right than on the left side. OA distributions by spinal segments in Koprivno and Sisak are similar: in Koprivno peak values are noted between L2 and L4, in Sisak between L2 and L5; two minor peaks are also observed in both samples: the first between C2 and C4, the second between T10 and T12 (Figs. 10 and 11).

At the level of the complete spine (cervical, thoracic, and lumbar + S1), males exhibit higher frequencies of OA than females in six of eight categories (range of χ^2 values from 6.108 to 42.884). The two exceptions are middle age individuals in Koprivno and young adults in Sisak where this trend is also noted but does not achieve significance.

Comparisons between the series show that Koprivno exhibits significantly higher OA frequencies in two of six categories: young females ($\chi^2 = 6.331$, $df = 1$, $P = 0.011$) and young males ($\chi^2 = 11.219$, $df = 1$, $P < 0.001$). Possibly more relevant to the questions addressed in this study is, however, the fact that Sisak exhibits higher frequencies of OA in three of six categories: older females ($\chi^2 = 8.486$, $df = 1$, $P = 0.004$), middle age males ($\chi^2 = 4.633$, $df = 1$, $P = 0.031$), and older males ($\chi^2 = 8.699$, $df = 1$, $P = 0.003$).

Concerning severity frequencies, at the level of total samples, OA severity frequencies follow the same pattern in both series. The most common manifestation of OA is slight, followed by severe and moderate (Table 6).With just one exception (in lumbar + S1 in Sisak) the same pattern is noted in all three analyzed spinal regions, as well as in both sexes.

Analyses carried out by sex show that males exhibit significantly more severe OA than females in five of eight analyzed categories: middle age, older and total male categories in Koprivno (χ^2 values: 14.335, 49.509 and 55.846, respectively), and older and total male

TABLE 3. VO frequencies by vertebral regions, sex, and age categories in Koprivno and Sisak

	Koprivno								Sisak							
	Cervical		Thoracic		Lumbar + S1		Total		Cervical		Thoracic		Lumbar + S1		Total	
Sex/age	*n/N*	%	*n/N*	%	*n/N*	%	*n/N*	%	*n/N*	%	*n/N*	%	*n/N*	%	*n/N*	%
F 15–30	1/41	2.4	1/81	1.2	0/29	0.0	2/151	1.3	0/32	0.0	0/73	0.0	0/21	0.0	0/126	0.0
F 31–45	7/51	13.7	29/101	28.7	11/49	22.4	47/201	23.4	3/77	3.9	81/208	38.9	38/92	41.3	122/377	32.4[a]
F 45+	32/57	56.1	84/116	72.4	51/63	81.0	167/236	70.8[a]	23/70	32.9	80/114	70.2	51/65	78.5	154/249	61.8
F total	40/149	26.8[a]	114/298	38.3	62/141	44.0	216/588	36.7	26/179	14.5	161/395	40.8	89/178	50.0	276/752	36.7
M 15–30	0/3	0.0	0/6	0.0	0/0	0.0	0/9	0.0	0/26	0.0	6/84	7.1	0/36	0.0	6/146	4.1
M 31–45	5/37	13.5	30/79	38.0	22/46	47.8	57/162	35.2[b]	11/96	11.5	116/282	41.1	55/121	45.5	182/499	36.5
M 45+	30/64	46.9	85/117	72.6	52/59	88.1	167/240	69.6	13/35	37.1	61/83	73.5	39/47	83.0	113/165	68.5
M total	35/101	34.7[a]	115/196	58.7[a,b]	74/105	70.5[a,b]	224/402	55.7[a,b]	24/157	15.3	183/449	40.8	84/204	41.2	301/810	37.1
Total	75/250	30.0[a]	229/494	46.4	136/246	55.3	440/990	44.4[a]	50/336	14.9	344/844	40.8	183/382	47.9	577/1,562	36.9

n = number of vertebral bodies exhibiting osteophytosis; *N* = number of examined vertebral bodies; % = percentage of vertebral bodies exhibiting osteophytosis.
[a] Significant differences between samples (total values only).
[b] Significant differences between sexes within a sample (total values only).

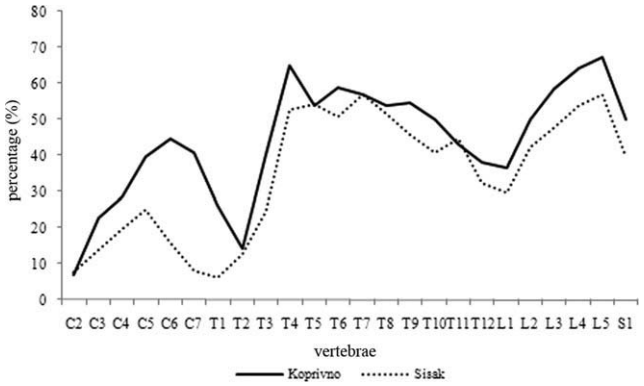

Fig. 8. Total VO frequencies by vertebrae in Koprivno and Sisak.

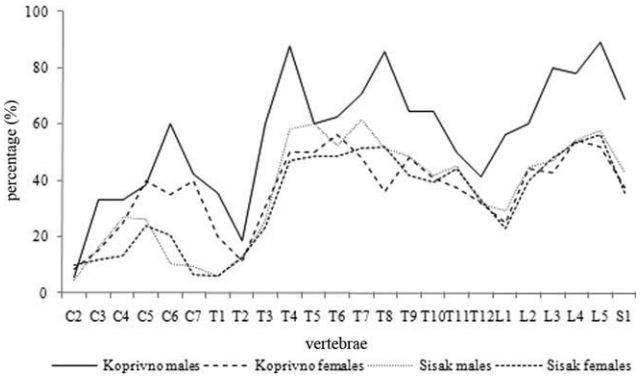

Fig. 9. VO frequencies by sex in Koprivno and Sisak.

categories in Sisak (χ^2 values: 52.746 and 25.702, respectively).

At the level of total samples, OA is significantly more severe in the Koprivno series ($\chi^2 = 63.945$, $df = 2$, $P < 0.001$). This trend is confirmed when the samples are analyzed by age and sex categories. Koprivno exhibits significantly more severe OA in four of six categories: middle age females ($\chi^2 = 8.923$, $df = 2$, $P = 0.01$), older females ($\chi^2 = 41{,}526$, $df = 2$, $P < 0.001$), middle-aged males ($\chi^2 = 14.032$, $df = 2$, $P < 0.001$), and older males ($\chi^2 = 21.926$, $df = 2$, $P < 0.001$).

In both series, higher OA frequencies are strongly correlated with older age categories (for Koprivno: $\chi^2 = 301.422$, $df = 2$, $P < 0.001$; for Sisak: $\chi^2 = 525.278$, $df = 2$, $P < 0.001$).

Comparison with other skeletal series

To put data from our study into a broader geographical frame, the results from Koprivno and Sisak are compared to other late Medieval and early Modern period skeletal series from: Klostermarienberg in Austria (Üstündağ, 2008), the battleship *Mary Rose* from England (Stirland and Waldron, 1997), a series from Norwich in England (Stirland and Waldron, 1997), and an additional Croatian series—Nova Rača (Šlaus, 2000).

The results, presented in Table 7, show that Koprivno compellingly leads all other samples in the frequencies of the analyzed vertebral pathologies. The only sample that exhibits frequencies of SN similar to Koprivno is Norwich (26% compared to Koprivno's 29.4%) while, for instance, the Klostemarienberg sample exhibits a frequency of SN that is more than four times lower than the one recorded in Koprivno. Similarly, when VO frequencies are compared, only Sisak exhibits values vaguely similar to those observed in Koprivno while *Mary Rose*, Nova Rača, and Norwich exhibit frequencies that are between four to five times lower. OA frequencies in Koprivno are again very high, almost three times those recorded in Klostermarienberg.

These comparisons, particularly those between VO and OA frequencies need, however, to be tempered by the fact that the compared series had very different age distributions, e.g., the majority of the *Mary Rose's* crew were men in their late teens or early twenties (Stirland and Waldron, 1997, p 334), while more than half of the Koprivno sample was aged over 45 years.

DISCUSSION

As previously noted, both historic and contemporary ethnographic sources suggest that the populations analyzed in this article led very different lifestyles. The main factors responsible for this were significantly

TABLE 4. VO severity by sex and age categories in Koprivno and Sisak

	Koprivno–Kod križa				Sisak–Sveti Križ			
Sex/age	SLI (%)	MOD (%)	SEV (%)	*n/N*	SLI (%)	MOD (%)	SEV (%)	*n/N*
F 15–30	2 (100.0)	0 (0.0)	0 (0.0)	2/151	0 (0.0)	0 (0.0)	0 (0.0)	0/126
F 31–45	45 (95.7)	2 (4.3)	0 (0.0)	47/201	119 (97.5)	3 (2.5)	0 (0.0)	122/377
F 45+	128 (76.6)	28 (16.8)	11 (6.6)	167/236	126 (81.8)	23 (14.9)	5 (3.3)	154/249
F total	175 (81.0)	30 (13.9)	11 (5.1)	216/588	245 (88.8)	26 (9.4)	5 (1.8)	276/752
M 15–30	0 (0.0)	0 (0.0)	0 (0.0)	0/9	6 (100.0)	0 (0.0)	0 (0.0)	6/146
M 31–45	48 (84.2)	5 (8.8)	4 (7.0)	57/162	152 (83.5)	25 (13.7)	5 (2.8)	182/499
M 45+	107 (64.1)	38 (22.7)	22 (13.2)	167/240	84 (74.3)	23 (20.4)	6 (5.3)	113/165
M total	155 (69.2)	43 (19.2)	26 (11.6)	224/402	242 (80.4)	48 (15.9)	11 (3.7)	301/810
Total	330 (75.0)	73 (16.6)	37 (8.4)	440/990	487 (84.4)	74 (12.8)	16 (2.8)	577/1,562

n = number of vertebral bodies exhibiting osteophytosis; *N* = number of examined vertebral bodies; % = percentage of vertebral bodies exhibiting some degree of osteophytosis; SLI = slight; MOD = moderate; SEV = severe.

different geographic–ecological systems that the analyzed populations inhabited, as well as significant differences in the characters of the analyzed populations: Sisak represents an affluent urban community, while Koprivno represents a poor rural community. Written sources do, however, suggest one characteristic common to both—a relatively strict sexual division of labor.

Comparing the frequencies and distributions of SN, VO, and OA between Koprivno and Sisak shows that while the distributions of these pathologies by spinal segments are very similar in both series, their total frequencies are, with a caveat for significantly different age distributions, as predicted by historical and contemporary ethnographic sources, significantly higher in Koprivno.

The distribution patterning of SN by vertebrae in Koprivno and Sisak is almost identical: in both samples SN occur more commonly in thoracic than in lumbar vertebrae; in the lumbar spine SN are much more frequent in upper than in lower vertebrae; SN are extremely rare in the upper thoracic region, and their highest frequency is observed in the lower thoracic region. This distribution mirrors the distribution of SN reported in other bioarchaeological and clinical studies that show that SN most frequently occur in the lower thoracic and upper lumbar vertebral regions (e.g., Hilton et al., 1976; Pfirrmann and Resnick, 2001; Üstündağ, 2008).

The significantly higher frequency of SN in males in both series is in accordance with data from numerous archaeological populations regardless of their chronological and geographical determination (e.g., Saluja et al., 1986; Šlaus, 2000; Üstündağ, 2008). Although some authors assume that sex-related differences may be associated with sex-related prenatal skeletal developmental differences (Saluja et al., 1986), or with the systematic influences that predispose males to have more SN (Jurmain, 1999), most authors explain these differences by mechanical influences (e.g., Rathbun, 1987; Robb, 1994; Üstündağ, 2008). The available historical and contemporary ethnographic sources for Koprivno and Sisak describe a sexual division of labor in both communities. Continuous stress related to the hard physical labor in which males from both samples partook may have been a cause of numerous torsional and compressional microtraumas on thoracic and lumbar vertebrae that ultimately led to the significantly higher SN frequencies recorded in males from both samples.

At this point it is, however, important to note that although both historical and contemporary ethnographic sources suggest a sexual division of labor in the two communities, this does not necessarily imply that female "household" tasks, particularly those in the rural Koprivno community, were less biomechanically stressful than male tasks. In fact, the similarities between total SN frequencies in Koprivno women and Sisak men, suggest that female household chores in the rural Koprivno community were similarly physically demanding to the high status, urban jobs that Sisak males had.

Total SN frequencies, as well as detailed analysis of SN frequencies by sex and age groups in Koprivno and Sisak are also in accordance with historical sources that suggest significantly different lifestyles, with an emphasis on higher levels of general physical stress in the Koprivno community.

Apart from the obvious lifestyle dissimilarity related to differences between rural and urban populations, an important contributing factor to this was the strictly enforced obligation for public labor or *kulluk* that the Ottoman authorities imposed on Koprivno males. Because Koprivno was located on the military border that separated the Ottoman Empire from Croatia, maintenance of the Klis fortress, located just 8 km south-west of the site, as well as of the surrounding roads, was of paramount military importance. While historical sources give no details as to how this was achieved in Koprivno, available data related to the reconstruction of the Požega fortress (a fortress similarly located on the military border but in the continental part of Croatia) indicate how large an endeavor this could be. The reconstruction of the Požega fortress involved the labor of almost 30,000 workers of which 4,097 were bricklayers, 2,806 were carpenters, 509 were smiths, an unknown number were teamsters, and 18,629 were unskilled peasants (Holjevac and Moačanin, 2007).

This labor requirement was enforced until the expulsion of the Turks in the late 17th century and the arrival of a new Croatian population from modern Bosnia and Herzegovina. Unfortunately, archaeological artifacts recovered from the cemetery do not allow us to differentiate between the two groups so we do not know precisely how many individuals in the Koprivno sample were under the *kulluk* obligation.

As in some other skeletal series (e.g., Saluja et al., 1986; Coughlan and Holst, 2000; Üstündağ, 2008) in both of the samples analyzed in this report SN frequencies show no association with increasing age. This is puzzling as one could reasonably expect that older age groups are associated with long-term exposures to various biomechanical stresses resulting in higher SN frequencies. A possible explanation put forward by

TABLE 5. OA frequencies by vertebral regions, sex, and age categories in Koprivno and Sisak

	Koprivno								Sisak							
	Cervical		Thoracic		Lumbar+S1		Total		Cervical		Thoracic		Lumbar+S1		Total	
Sex/age	*n/N*	%	*n/N*	%	*n/N*	%	*n/N*	%	*n/N*	%	*n/N*	%	*n/N*	%	*n/N*	%
F 15–30	17/104	16.3	49/180	27.2	27/85	31.8	93/369	25.2[a]	7/76	9.2	20/136	14.7	18/59	30.5	45/271	16.6
F 31–45	18/116	15.5	64/197	32.5	67/98	68.4	149/411	36.3	41/166	24.7	122/394	31.0	92/199	46.2	255/759	33.6
F 45+	86/140	61.4	152/252	60.3	114/130	87.7	352/522	67.4	98/148	66.2	139/180	77.2	90/101	89.1	327/429	76.2[a]
F total	121/360	33.6	265/629	42.1	208/313	66.5[a]	594/1,302	45.6	146/390	37.4	281/710	39.6	200/359	55.7	627/1,459	43.0
M 15–30	3/6	50.0	9/14	64.3	0/2	0.0	12/22	54.5[a,b]	10/67	14.9	23/145	15.9	31/94	33.0	64/306	20.9
M 31–45	16/72	22.2	46/140	32.9	60/78	76.9	122/290	42.1	68/191	35.6	219/497	44.1	177/249	71.1	464/937	49.5[a,b]
M 45+	101/153	66.0	182/252	72.2	108/116	93.1	391/521	75.0[b]	67/77	87.0	132/167	79.0	93/105	88.6	292/349	83.7[a,b]
M total	120/231	51.9[b]	237/406	58.4[a,b]	168/196	85.7[a,b]	525/833	63.0[a,b]	145/335	43.3	374/809	46.2[b]	301/448	67.2[b]	820/1,592	51.5[b]
Total	241/591	40.8	502/1,035	48.5[a]	376/509	73.9[a]	1,119/2,135	52.4[a]	291/725	40.1	655/1,519	43.1	501/807	62.1	1,447/3,051	47.4

n = number of articular facets exhibiting osteoarthritis; *N* = number of examined articular facets; % = percentage of articular facets exhibiting osteoarthritis.
[a] Significant differences between samples (total values only).
[b] Significant differences between sexes within a sample (total values only).

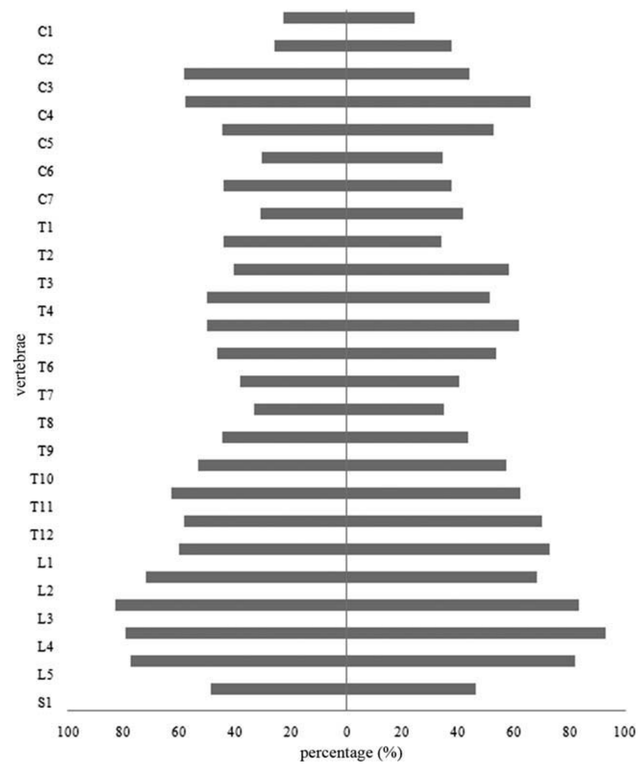

Fig. 10. Total OA frequencies by sides in Koprivno.

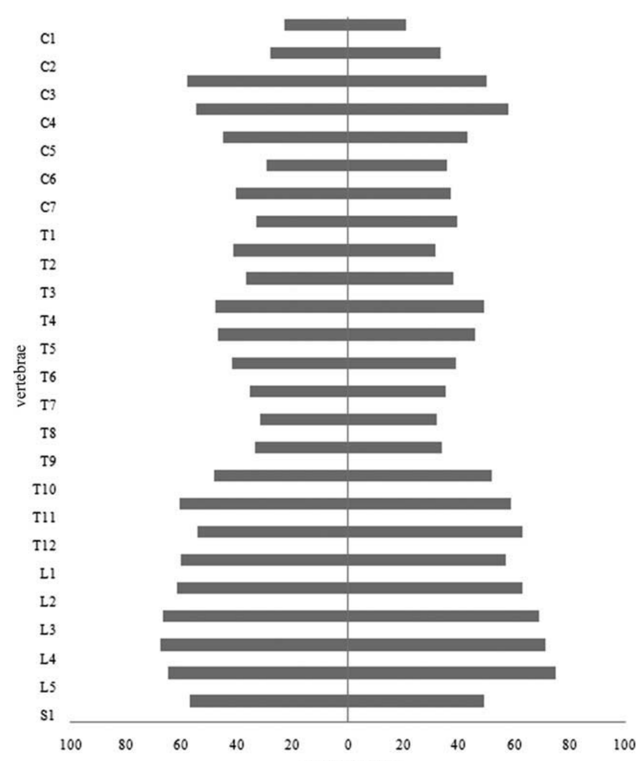

Fig. 11. Total OA frequencies by sides in Sisak.

TABLE 6. OA severity by sex and age categories in Koprivno and Sisak

	Koprivno–Kod križa				Sisak–Sveti Križ			
Sex/age	SLI (%)	MOD (%)	SEV (%)	*n/N*	SLI (%)	MOD (%)	SEV (%)	*n/N*
F 15–30	93 (100.0)	0 (0.0)	0 (0.0)	93/369	41 (91.1)	4 (8.9)	0 (0.0)	45/271
F 31–45	137 (91.9)	1 (0.7)	11 (7.4)	149/411	234 (91.8)	13 (5.1)	8 (3.1)	255/759
F 45+	246 (69.9)	56 (15.9)	50 (14.2)	352/522	292 (89.3)	12 (3.7)	23 (7.0)	327/429
F total	476 (80.1)	57 (9.6)	61 (10.3)	594/1,302	567 (90.4)	29 (4.6)	31 (5.0)	627/1,459
M 15–30	12 (100.0)	0 (0.0)	0 (0.0)	12/22	54 (84.4)	4 (6.2)	6 (9.4)	64/306
M 31–45	96 (78.7)	12 (9.8)	14 (11.5)	122/290	419 (90.3)	27 (5.8)	18 (3.9)	464/937
M 45+	240 (61.4)	21 (5.4)	130 (33.2)	391/521	190 (65.1)	40 (13.7)	62 (21.2)	292/349
M total	348 (66.3)	33 (6.3)	144 (27.4)	525/833	663 (80.8)	71 (8.7)	86 (10.5)	820/1,592
Total	824 (73.6)	90 (8.1)	205 (18.3)	1,119/2,135	1,230 (85.0)	100 (6.9)	117 (8.1)	1,447/3,051

n = number of articular facets exhibiting osteoarthritis; *N* = number of examined articular facets; % = percentage of articular facets exhibiting some degree of osteoarthritis; SLI = slight; MOD = moderate; SEV = severe.

TABLE 7. Comparison of total frequencies of SN, VO, and OA in several skeletal series

Site	SN	VO	OA
Koprivno, Croatia	29.4	44.4	52.4
Sisak, Croatia	17.6	36.9	47.4
Nova Rača, Croatia	15.6	11.6	X
Klostermarienberg, Austria	7.0	30.5	17.9
Mary Rose, England	19.5	8.5	X
Norwich, England	26.0	10.0	X

Chandraraj et al. (1998) is that SN occur more frequently in younger individuals because their intervertebral discs are tumid, and the outer annulus fibrosus is very strong—thus the nucleus pulposus can easily herniate through the weak areas into the endplate. This hypothesis would be strengthened if higher frequencies of SN were correlated with younger age categories; however, that is not case in our data set. In Koprivno, SN frequencies increase from young adults to middle-aged adults, and then decrease in older adults, while in Sisak these frequencies generally remain very similar although they do continuously decrease from the younger, through the middle age to the older age group.

In conclusion, the results of our analysis show that Koprivno exhibits significantly higher frequencies of SN than Sisak in four of six analyzed categories, while males exhibit higher SN frequencies than females in five of eight available categories. These results are, therefore, similar to the results recorded by Stirland and Waldron (1997), Šlaus (2000), and Üstündağ (2008) that suggest that SN can be used as a reliable indicator of activity-related stress and different lifestyles in archaeological populations.

The VO distribution patterns in Koprivno and Sisak are almost identical to the distribution patterns recorded in numerous other archaeological populations from different parts of the world (e.g. Bridges, 1994; Stirland and Waldron, 1997; Sofaer Derevenski, 2000) and are thus most likely a result of the normal curvature of the vertebral column. In a healthy spine, natural curvature moderates the transfer of weight down the spinal column, and skeletal changes of the vertebral bodies reflect this curvature. These changes are most severe in places where the curvatures are furthest away from the line of gravity and least where the vertebral column passes through the line of gravity (Sofaer Derevenski, 2000, p 350). Consequently, the highest involvement for the cervical region is usually found in the C5/C6 region (e.g. Merbs, 1983; Bridges, 1994; van der Merwe et al., 2006). In the thoracic region, the maximum curvature of the spine is usually found in T7/T8 (e.g., Nathan, 1962; Merbs, 1983; Üstündağ, 2008). Sisak adheres to this pattern, while the highest involvement in the thoracic region in Koprivno is found slightly higher—between T4 and T6. The most affected vertebrae in the lumbar region are usually L3 and L4, although L2/L3 and L4/L5 may also exhibit high frequencies (Bridges, 1994). The lowest VO frequencies, according to Nathan (1962), should be recorded in vertebrae lying along the center of gravity—at about T1, T12, and L5/S1. Both of the series analyzed in this report in principle follow this pattern.

Analysis of VO frequencies between Koprivno and Sisak, by age and sex groups, reveals a complex picture with, at best, mixed trends. Koprivno exhibits higher VO frequencies without achieving significance in younger females, older females, and older males, while Sisak exhibits higher VO frequencies in younger males, middle-aged males and middle-aged females. Of importance is the fact that only two significant differences between the series are noted. Older females from Koprivno exhibit significantly higher frequencies of VO than older females from Sisak, while middle-aged females from Sisak exhibit significantly higher VO than middle-aged females from Koprivno.

Comparisons between the sexes in the analyzed sites are also inconclusive. Males exhibit higher VO frequencies than females in only 2/8 analyzed categories, both of them in Koprivno.

In both Croatian series, thoracic vertebrae exhibited lower frequencies of severe VO in comparison to cervical and lumbar vertebrae. This pattern has been observed by other authors (e.g., Hollinshead, 1969; van der Merwe et al., 2006) and explained (Hollinshead, 1969) by the fact that thoracic vertebrae are, because of their articulation with the ribs, less mobile than other vertebrae, and thus less susceptible to the occurrence of the more severe degrees of VO that are recorded in other spinal regions.

Analyses of the severity of VO in Koprivno and Sisak show no significant differences between any of the six analyzed age categories. In contrast, comparisons between the severity of VO in males and females show that males exhibit significantly more severe VO than females in four of eight available categories (two from Koprivno, and two from Sisak).

The OA distribution patterning in Koprivno and Sisak is, as in numerous other studies (e.g. Bridges, 1994; Lovell, 1994; Knüsel et al., 1997), somewhat different from the pattern of VO. These differences are expected, as intervertebral joints and articular facets play different

roles in the vertebral column: articular facets are responsible for the movement of the spine, while intervertebral joints are in charge of support and weight-bearing.

Analyses of OA frequencies between Koprivno and Sisak, carried out by age and sex groups, reveal mixed trends. Koprivno exhibits higher OA frequencies in two of six categories, while Sisak exhibits higher frequencies of OA in three of six categories. Comparisons between the sexes in the analyzed sites are less ambiguous: males exhibit higher OA frequencies than females in six of eight analyzed categories—three from Koprivno, and three from Sisak.

Analyses of the severity of OA in Koprivno and Sisak are more in keeping with the available historical and contemporary ethnographic sources. Koprivno exhibits more severe OA changes than Sisak in four of six analyzed categories. Possibly equally important is the fact that Sisak does not exhibit more severe OA in any of the compared categories. Analyses made by sex show that males exhibit more severe OA changes than females in five of eight analyzed categories.

Summing up the results of the analyses of VO and OA frequencies and severity in Koprivno and Sisak suggests that they cannot be interpreted in keeping with the historical and contemporary ethnographic sources. Coupled with the fact that factors other than mechanical stress can result in different VO and OA frequencies (Weiss and Jurmain, 2007), as well as the fact that unlike SN the occurrence of VO and OA in both series is highly correlated with advanced age categories, it appears that these pathologies may not be reliable indicators of activity-related stress in archaeological populations. Of interest is the fact that in both pathologies male/female differences are more pronounced, and more uniform—in the sense that females do not exhibit higher frequencies or more severe expressions in any of the analyzed categories, than differences between the sites.

This could be related to factors such as genetic influences that have in modern clinical research been identified as possible causative agents in the development of vertebral osteoarthritis (VO and OA), nutritional factors, or differences in body sizes between the sexes.

Concerning the first—unfortunately no specific information regarding relatedness is currently available, even for the high status cemetery in Sisak. Church records are available for some early Modern period sites in Croatia and have in fact been successfully utilized in biocultural studies of Croatian osteological series (Šlaus, 2000), but the records from Sisak were destroyed during the Second World War.

Concerning nutritional factors—contemporary ethnographic data imply that the nutrition of the rural populations in the Dalmatian hinterland was uniform and modest. It was dominated by bread made of barley, rye, corn or oats, vegetables such as beans, peas, onions, and leeks, while fresh, dried, and salted meat (mostly beef, sheep, and goat) was usually consumed during holidays (Obad, 1990; Peričić, 1998). There is no data that would suggest that males and females consumed different diets. The nutrition of the urban early Modern period populations from continental Croatia primarily consisted of bread made of corn and wheat, vegetables such as cabbage, pumpkin, and onion, while meat consumption was limited to pigs, goats, sheep, and poultry that were, again, usually consumed during important Church holidays (Matić, 1951; Relković, 1994). Again, there are no data that would suggest different diets between males and females. The available written sources, therefore, suggest that males and females consumed the same diets in both sites, and that while clear economic and social differences existed between these communities, their nutrition was in general similar: dominated by cereals and vegetables, while meat was infrequent and limited to important occasions. It, therefore, seems probable that the nutritional habits of the analyzed communities did not play a part in the observed differences between the frequencies of the analyzed vertebral pathologies.

It is possible that the higher frequencies and severity of VO and OA changes noted in males is related to differences in body size between males and females. Males are generally more robust than females, and consequently have greater body weights that exert more pressure on the spine (van der Merwe et al., 2006). In theory, this can result in a higher frequency and severity of VO and OA changes.

In conclusion, the results of our study suggest that while SN are useful indicators of different lifestyles and/or different activity patterns between various archaeological populations, as well as between sexes in a particular site, VO and OA are, possibly because of the different etiologies of these pathologies and the huge role that factors other than mechanical stress have in their development, not as useful indicators of activity-related stress. Obviously, as the etiologies of SN, VO, and OA in archaeological and modern populations are still not completely clarified, further research of archaeologically derived skeletal samples, particularly those with relevant and abundant historical and ethnographic data is necessary if our conclusions are to be verified.

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