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Vertebral Pathologies and Related Activity Patterns in two Mediaeval Populations from Spain

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A B S T R A C T

The main aim of this study was to explore the usefulness of several types of vertebral pathology as activity markers in osteological populations. A total of 2165 vertebrae from 124 individuals were studied. They were derived from cemeteries in two villages: Villanueva de Soportilla (Burgos, north of Spain), with a Christian population, and La Torrecilla (Granada, south of Spain), inhabited by Muslims. Degenerative joint diseases, Schmorl's nodes, compression fractures and spondylolysis with spondylolisthesis were analysed in individuals and separate vertebral pieces. All pathological conditions, except compression fractures, were significantly more frequent in males than in females, reflecting more intensive labour conditions for males. They were significantly more frequent in males from Villanueva, a border population of peasant-soldiers, than in males from La Torrecilla. They were also significantly more frequent in females from Christian Villanueva than in those from Muslim La Torrecilla, where the women mainly worked at home. The benefits and limitations of the study of these vertebral pathologies are discussed.

***Key words**: degenerative joint diseases, Schmorl's nodes, spondylolysis, activity patterns, Middle Ages*

Introduction

Considerable attention has been paid to the study of diseases and musculoskeletal stress markers as indicators of physical activity in the past. There have been several paleopathological investigations on the relationship between physical activity and the anatomy of the vertebral column[1–11]. Reports in the medical literature describe intense physical activity as an important contributory factor to some types of spinal injury[12]. However, questions have been raised about the value of these lesions as activity markers, since physical activity is only one among multiple factors influencing their development[11,13–16].

The main aims of this study were to analyse the presence of several pathological conditions and their association with intense physical activity and to determine whether they can serve as reliable activity markers in osteological populations. These pathologies include degenerative joint diseases, such as degenerative disk disease (DDD), and vertebral osteoarthritis (VOA), Schmorl's nodes, compression fractures and spondylolysis with spondylolisthesis, which are very common findings in archaeological bones. Compression fractures, spondylolysis and Schmorl's nodes were previously analysed in a Bronze Age population[4]. The authors called for »similar studies of other populations with known activity patterns must be performed to establish whether detection of this type of disease can offer insights into the physical activity of past populations«. The same pathological conditions were examined in the present study with the addition of spinal degenerative joint diseases (DDD and VOA), also frequently observed in ancient skeletons.

Collections of skeletons from two mediaeval populations, the Christian Villanueva de Soportilla (Burgos, North of Spain) and the Muslim La Torrecilla (Granada, South of Spain) were selected for study. The populations were contemporaneous (Villanueva dated from 850–1100 AD and Torrecilla dated from 900–1300 AD) and of similar size. Both were located in flat-land rural environments and had agricultural economies. The tombs did not indicate social status. Both sites were located far from large urban centres or major routes. Earlier works suggested that both populations were comprised of peasants with scant economic resources[17,18].

There were some known differences in the activity pattern of these populations. Although both economies

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were based on agriculture, the land used by the peasants in Villanueva was granted by King Alfonso III as a reward for defending the border area. Therefore, the males in Villanueva are considered to be peasant-soldiers, with harsher life conditions than the males from La Torrecilla[17,19]. The historical records also reveal[20] that the females in Villanueva collaborated actively with the males in several agricultural tasks, whereas the women in La Torrecilla largely worked at home.

Previous osteological analyses of these populations indicated a clear difference in activities between the males and females[21,22]. In particular, the presence and distribution of musculoskeletal markers, traumas and osteoarthritis in males of both populations suggest a greater intensity of physical activity and risk of suffering accidents than in females. Males showed a much higher level of muscle development than females and a greater incidence of skull traumas and degenerative joint disease.

Given the known activity patterns of the males and females in the two populations, we hypothesized that males in both villages would show a higher incidence of vertebral lesions in comparison to the females. Due to their participation in agricultural work, a higher frequency of lesions was expected in the females from Villanueva than in those from La Torrecilla. Higher lesion frequencies were also expected in the Villanueva population as a whole, given the harder life conditions indicated by their role as a border population of peasant-soldiers.

Materials and Methods

Skeletal remains from Villanueva de Soportilla and La Torrecilla were examined. The cemetery of Villanueva was discovered by A. del Castillo in 1970. Here, the tombs were excavated in a rocky area and had an anthropomorphical or rectangular form. The bodies were lying in a supine position on their backs[17,19]. The cemetery of La Torrecilla was excavated from 1968 to 1976 by A. Arribas, M. Riu and Ph. du Souich. In this case, the skeletons were lying on their right sides in direct contact with the earth[18]. The position of the skeletons does not appear to determine the degree of preservation, which is more dependent on the soil conditions.

The studied series of skeletal remains comprised individuals over 20 years old whose sex and age have been assessed by generally accepted methods[23,24] and whose vertebral columns were at least 50% preserved. The sample consisted of 50 individuals (26 males and 24 females) from the Villanueva collection and 74 individuals (39 males and 35 females) from La Torrecilla.

Because most of the pathological conditions studied are also related to aging, the age distribution of the two samples was compared to evaluate whether age was a potential confounding factor in the analyses. The age distribution of the samples did not significantly differ for either males or females (chi-square analysis with the Microstat program). Among the males, there were 16 adults (21–40 yrs) (61.5%) and 10 mature/senile individuals (≥41 years) (38.5%) in the Villanueva sample, *versus* 24 adults (61.5%) and 15 mature/senile individuals (38.5%) from La Torrecilla ($p=0.79$). Among the females, there were 17 adults (70.8%) and 7 mature/senile individuals (29.2%) from Villanueva vs. 25 adult females (71.4%) and 10 mature/senile individuals (28.6%) from La Torrecilla. Again, no significant difference was found ($p=0.81$) between Villanueva and La Torrecilla. A total of 2165 vertebrae (72.75% of the expected number) were available for study (425 from males and 341 from females of Villanueva, and 755 from males and 644 from females of La Torrecilla).

The distribution of lesions among cervical, thoracic and lumbar sectors was recorded by sex, age and population for individuals and separate vertebral specimens, with the criterion of presence or absence. Degenerative joint diseases was recorded from the status of the vertebral bodies (degenerative disk degeneration or DDD) and from the apophyseal joints (vertebral osteoarthritis or VOA)[12]. In the case of compression fractures, it was noted whether the vertebral body was homogeneously flattened or had a wedge shape[26]. Signs of disk herniations into the vertebral endplates (Schmorl's nodes) were recorded, noting their location at the upper and/or lower surface of vertebral bodies and whether the location of the disk protrusion was central, adjacent to the spinal canal or peripheral[4]. Data were also gathered on the presence of spondylolysis and spondylolisthesis in vertebrae L4 and L5 and in the lumbo-sacral joint.

Results

Degenerative joint diseases (DDD and VOA) (Figure 1) were significantly more frequent in mature/senile individuals than in younger individuals from both populations (Table 1). Other differences observed (higher frequency in males *versus* females and in Villanueva *versus* La Torrecilla) were not statistically significant.

A significantly ($p<0.001$) higher number of affected vertebrae was found in mature/senile vs. younger individuals (Tables 2 and 3). A higher percentage of vertebrae were affected in the Villanueva males (30.8%) than in the females (19.1%; $p<0.001$). In the sample from La Torrecilla, the percentage of affected vertebrae was higher for males than for females (13.1% *vs.* 6.7%; $p<0.001$) (Table 3). There was a highly significant ($p<0.001$) difference in the percentage of affected vertebrae between Villanueva males (30.8%) and La Torrecilla males (13.1%) and between Villanueva females (19.1%) and La Torrecilla females (6.7%).

In the males from La Torrecilla and the females from Villanueva, the distribution of degenerative joint diseases by vertebral sectors denotes greater involvement in the lumbar followed by cervical and thoracic sectors. The distribution in the females from La Torrecilla could not be assessed, because too few cases were available for study. In the Villanueva males, the lumbar was more affected than the thoracic sector, which was slightly more affected than the cervical sector.

Fig. 1. a) Compression fractures in lumbar vertebrae, b) Spondylolysis, c) 1: degenerative joint diseases, 2: Schmorl's node.

TABLE 1
DISTRIBUTION OF LESIONS BY INDIVIDUALS, SEX AND AGE IN BOTH POPULATIONS WITH CHI-SQUARE AND PROBABILITY VALUES

V				DJD					SN					CF		
Sex	Age	N	n	%	χ^2	p	N	n	%	χ^2	p	N	n	%	χ^2	p
M	A	16	2	12.5	15.6	<0.001	16	9	56.3	0.01	0.92	16	1	6.3	6.5	0.01
M	M/S	10	10	100			10	5	50.0			10	6	60.0		
Tm		26	12	46.2			26	14	53.8			26	7	26.9		
M/F					0.89	0.34				5.96	0.01				0.03	0.86
F	A	17	2	11.8	5.90	0.02	17	3	17.6	0.16	0.69	17	1	5.9	5.10	0.02
F	M/S	7	5	71.4			7	1	14.3			7	4	57.1		
Tf		24	7	29.2			24	4	16.7			24	5	20.8		
T				DJD					SN					CF		
Sex	Age	N	n	%	χ^2	p	N	n	%	χ^2	p	N	n	%	χ^2	p
M	A	24	5	20.8	4.57	0.03	24	8	33.3	0.00	0.94	24	2	8.3	0.32	0.57
M	M/S	15	9	60.0			15	6	40.0			15	3	20.0		
Tm	39	14	35.9				39	14	35.9			39	5	12.8		
M/F					0.94	0.33				6.32	0.01				0.02	0.87
F	A	25	2	8.0	8.20	<0.001	25	3	12.0	0.23	0.63	25	2	8.0	1.31	0.25
F	M/S	10	6	60.0			10	0	—			10	3	30.0		
Tf		35	8	22.9			35	3	8.6			35	5	14.3		

V – Villanueva, T – Torrecilla, DJD – degenerative joint diseases, SN – Schmorl's nodes, CF – compression fractures, M – males, F – females, M/F – males vs. females, A – adults, M/S – mature/senile

Schmorl's nodes (Figure 1) in individuals (Table 1) and in separated vertebral specimens (Tables 2 and 3) did not differ in frequency as a function of age in either sample, with a similar distribution between adult and mature/senile individuals in both populations. Schmorl's nodes were significantly (p=0.01) more frequent in males *versus* females in both samples (Villanueva: 53.8% of males *vs*. 16.7% of females; La Torrecilla; 35.9% of males and 8.6% of females).

TABLE 2
DISTRIBUTION OF LESIONS BY VERTEBRAL PIECES, SEX AND AGE IN VILLANUEVA DE SOPORTILLA

DJD

	M A			M M/S			M Tot			F A			F M/S			F Tot		
	N	n	%	N	N	%	N	n	%	N	n	%	N	n	%	N	n	%
C	66	0	–	51	27	52.9	117	27	23.1	71	8	11.3	28	16	57.1	99	24	24.2
T	117	4	3.4	95	57	60.0	212	61	28.8	113	5	4.4	47	10	21.3	160	15	9.4
L	48	3	6.3	48	40	83.3	96	43	44.8	59	8	13.6	23	18	78.3	82	26	31.7
Tot	231	7	3.0	194	124	63.9	425	131	30.8	243	21	8.6	98	44	44.9	341	65	19.1

SN

	M A			M M/S			M Tot			F A			F M/S			F Tot		
	N	n	%	N	N	%	N	n	%	N	n	%	N	n	%	N	n	%
C	66	0	–	51	0	–	117	0	–	71	0	–	28	0	–	99	0	–
T	117	18	15.4	95	16	16.8	212	34	16.0	113	4	3.5	47	1	2.1	160	5	3.1
L	48	5	10.4	48	1	2.1	96	6	6.3	59	3	5.1	23	0	–	82	3	3.7
Tot	231	23	10.0	194	17	8.8	425	40	9.4	243	7	2.9	98	1	1.0	341	8	2.3

CF

	M A			M M/S			M Tot			F A			F M/S			F Tot		
	N	n	%	N	N	%	N	n	%	N	n	%	N	n	%	N	n	%
C	66	0	–	51	0	–	117	0	–	71	0	–	28	0	–	99	0	–
T	117	1	0.9	95	9	9.5	212	10	4.7	113	0	–	47	1	2.1	160	1	0.6
L	48	0	–	48	7	14.6	96	7	7.3	59	1	1.7	23	10	43.5	82	11	13.4
Tot	231	1	0.4	194	16	8.2	425	17	4.0	243	1	0.4	98	11	11.2	341	12	3.5

DJD – degenerative joint diseases, SN – Schmorl's nodes, CF – compression fractures, M – males, F – females, A – adults, M/S – mature and senile, Tot – total, C – cervical, T – thoracic, L – lumbar

With regard to separated specimens, a significantly higher percentage ($p<0.001$) of affected vertebrae was detected in males than in females (Tables 2 and 3). The distribution of lesions in relation to the surfaces of vertebral bodies was similar for the upper and lower endplates in both samples and sexes. Nodes were more frequently found in lower thoracic and lumbar vertebrae and were absent in the cervical sector[10]. A central localization in the endplate was the most frequent position (92% of cases). Lesions on the periphery were rare, a finding that coincides with the distribution usually found[4,14].

There was a significantly ($p=0.04$) higher percentage of affected vertebrae in the Villanueva female sample (2.3%) than in the La Torrecilla female sample (0.6%) (Tables 2 and 3). Other differences by population and sex did not reach significance.

Compression fractures (Figure 1) (Table 1) were more frequent in older individuals, both in males and females. The difference was significant for the Villanueva sample (males, $p=0.01$; females, $p=0.02$). No significant difference was found between the sexes in either sample or between the samples. Further, study of the vertebrae (Tables 2 and 3) showed a significantly higher percentage of affected specimens in the Villanueva *versus* La Torrecilla males (4.0% *vs*. 0.8%; $p<0.001$) and in the Villanueva *versus* La Torrecilla females (3.5% *vs*. 1.2%; $p=0.03$).

Spondylolysis was detected in only three males (21/3/14.3%) in Villanueva and in only one male (35/1/2.9%) and two females (28/2/7.1%) in La Torrecilla, with the presence of a complicating spondylolisthesis in all cases.

Discussion

Spinal degenerative joint diseases (DDA and VOA) may be related to intense physical activity, but various factors may contribute to its pathogenesis[11,15,25]. Importantly, it is closely related to age[26,27], therefore a high incidence may indicate the longer life span of a group rather than its intense physical activity. Genetic factors can also contribute. Therefore, genetically distant populations should not be compared. Development of this joint degeneration can also be influenced by anatomical differences and repetitive mechanical traumas (secondary degenerative disc disease and vertebral osteoarthritis). Obesity is a potentially very important factor that cannot be assessed in osteological populations, although

TABLE 3
DISTRIBUTION OF LESIONS BY VERTEBRAL PIECES, SEX AND AGE IN LA TORRECILLA

DJD

	M A			M M/S			M Tot			F A			F M/S			F Tot		
	N	n	%	N	n	%	N	n	%	N	n	%	N	n	%	N	n	%
C	125	9	7.2	75	13	17.3	200	22	11.0	132	3	2.3	41	9	22.0	173	12	6.9
T	235	6	2.6	161	31	19.3	396	37	9.3	246	4	1.6	81	19	23.5	327	23	7.0
L	90	11	12.2	69	29	42.0	159	40	25.2	107	0	–	37	8	21.6	144	8	5.6
Tot	450	26	5.8	305	73	23.9	755	99	13.1	485	7	1.4	159	36	22.6	644	43	6.7

SN

	M A			M M/S			M Tot			F A			F M/S			F Tot		
	N	n	%	N	n	%	N	n	%	N	n	%	N	n	%	N	n	%
C	125	0	–	75	0	–	200	0	–	132	0	–	41	0	–	173	0	–
T	235	29	12.3	161	22	13.7	396	51	12.9	246	1	0.4	81	0	–	327	1	0.3
L	90	4	4.4	69	6	8.7	159	10	6.3	107	3	2.8	37	0	–	144	3	2.1
Tot	450	33	7.3	305	28	9.2	755	61	8.1	485	4	0.8	159	0	–	644	4	0.6

CF

	M A			M M/S			M Tot			F A			F M/S			F Tot		
	N	n	%	N	n	%	N	n	%	N	n	%	N	n	%	N	n	%
C	125	0	–	75	0	–	200	0	–	132	0	–	41	0	–	173	0	–
T	235	1	0.4	161	1	0.6	396	2	0.5	246	1	0.4	81	4	4.9	327	5	1.5
L	90	1	1.1	69	3	4.3	159	4	2.5	107	1	0.9	37	2	5.4	144	3	2.1
Tot	450	2	0.4	305	4	1.3	755	6	0.8	485	2	0.4	159	6	3.8	644	8	1.2

DJD – degenerative joint diseases, SN – Schmorl's nodes, CF – compression fractures, M – males, F – females, A – adults, M/S – mature and senile, Tot – total, C – cervical, T – thoracic, L – lumbar

we assume that it would have had considerably less influence than in affluent contemporary western societies.

The present findings correlate with the known historical data on physical activity in the two study populations. Evidence of spinal degenerative joint disease was found significantly more frequently in males from Villanueva than in those from La Torrecilla (30.8% *vs.* and 13.1%) and is consistent with the harsher life conditions of this border population, made up of peasant-soldiers. In addition, a higher frequency was observed in the males than females of both populations, in line with expectations that the males would have carried out more intense physical activities. Finally, a higher frequency was observed in women from Villanueva than in those from La Torrecilla, which correlates with the lesser participation of the Muslim women in agricultural work in comparison to their Christian counterparts[20].

The distribution of degenerative joint diseases by vertebral sector coincides with spine biomechanics[28]. The distribution in Villanueva and La Torrecilla coincides with that in males from the Bronze Age El Argar culture in the South East of the Iberian Peninsula (C: 21.3%; T: 26.5%; L: 46.8%)[29]. Although this can be attributed to the practice of certain intense physical activities, such as carrying loads on the back, this would be impossible to verify. Higher frequencies of degenerative spinal joint diseases were reported for skeletons from the El Argar culture (El Argar: 53.1% of males, 46.7% of females; Villanueva: 46.2% of males, 29.2% of females; Torrecilla: 35.9% of males, 22.9% of females). Given the similar age distribution of the three groups, these findings indicate that physical activity might have played a major role in the pathology but do not specify the type of task that was responsible.

Although there is relative consensus in the literature that the presence of Schmorl's nodes is an indicator of physical activity, they can also be associated with trauma, congenital disorders and degenerative processes[3,14,25]. Adolescence is the main time of onset, which would explain the similarity in frequencies between adult and mature or senile individuals in our series. The distribution of Schmorl's nodes is usually observed in current and osteological populations[3,14] and is attributed to the anatomy and biomechanics of the lower spine[28]. Schmorl's nodes were more frequently detected in males than in females in both populations, reflecting the more demand-

ing physical activities carried out by the males[2,4,14]. The higher frequency *per* individual of nodes in the Villanueva males than in the La Torrecilla males is consistent with the historical data and musculoskeletal studies[21]. The higher frequency of affected vertebrae in the Villanueva females than in the La Torrecilla females is also consonant with the historical data on their greater participation in agricultural tasks.

The proportion of males with Schmorl's nodes in the Villanueva sample (53.8%) is very similar to the proportion (56.6%) reported in the El Argar males[4]. Both groups are known to have practised strenuous physical activities. However, the frequency in El Argar females (30.8%) was much higher than in Villanueva (16.7%) or La Torrecilla (8.6%) females, while the same criteria were applied in both studies. This difference may be explained by the much harsher environment for the Bronze Age women.

Compression fractures can be produced by an intense axial force, as seen in the lifting of a heavy weight, a fall, or a blow on the back or shoulders[30]. However, another important contributing factor is bone fragility due to osteoporosis or other diseases. In the present samples, compression fractures were more frequent at higher ages, which may reflect more years of exposure to intense compression fractures, since few individuals reached the age (>70 yrs) when senile osteoporosis could be expected[31].

The number of affected vertebral specimens in the Villanueva males again suggests their more intense physical activity, in agreement with the historical data. The similar number of compression fractures in the females may be attributable to post-menopausal osteoporosis, since authors have reported a higher frequency of this lesion in females than in males[4,32].

Spondylolysis is usually related to the practice of intense repetitive physical activity[33,34]. The low percentage of individuals exhibiting this pathology in the present collections (37/3/8.1% in Villanueva and 63/3/4.8% in Torrecilla) is similar to the 5% reported in current populations[35] but higher than the proportion (3.2%) in the El Argar sample[4]. As also commented in the El Argar study, the small number of individuals with spondylolysis in the samples does not allow this type of injury to be proposed as a marker of activity patterns, since the results can be attributed to chance. A further shortcoming of spondylolysis as a marker is the inability to compare among very different populations, because of the influence of genetic factors on the disease[7,36,37]. The level of skeletal preservation can also affect spondylolysis detection[38].

Conclusions

This study found a significantly higher frequency of spinal pathological conditions in the males and females from Villanueva de Soportilla than in the males and females from La Torrecilla settlement, respectively (Figures 2 and 3), with the exception of Schmorl's nodes in the females. These observations are in accord with the historical data, which suggest that both sexes in the

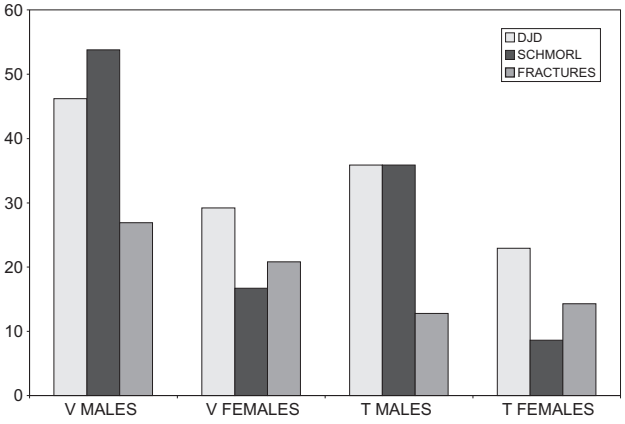

Fig. 2. Distribution in percentages (y axis) of degenerative joint diseases (DJD), Schmorl's nodes and compression fractures by individuals according to site (V: Villanueva de Soportilla; T: La Torrecilla) and sex (x axis).

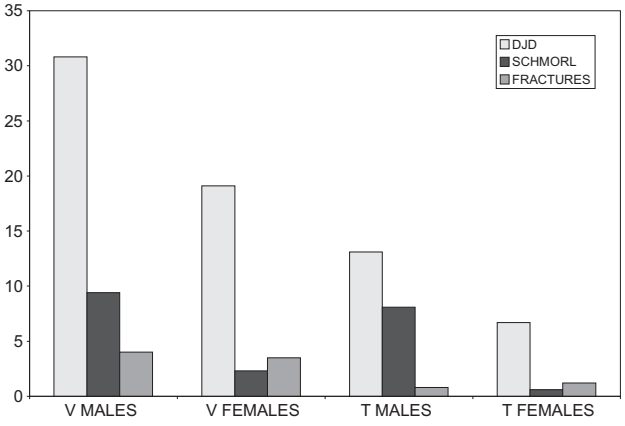

Fig. 3. Distribution in percentages (y axis) of degenerative joint diseases (DJD), Schmorl's nodes and compression fractures by vertebral pieces according to site (V: Villanueva de Soportilla; T: La Torrecilla) and sex (x axis).

Christian peasant-soldier border village would have had higher activity levels in comparison to their exclusively peasant counterparts in Muslim La Torrecilla. These populations lived in small villages, and specialized artisans would be based in larger villages or towns at this time.

Although multiple factors can be implicated in osteoarthritis of the spine, our findings suggest that it can be a useful activity marker for comparisons among populations with a similar age distribution and genetic origin.

The comparisons by individual and by vertebral pieces yielded different results, indicating that both approaches should be used when populations are compared. Schmorl's nodes appear to be a good activity marker, but numerous factors can be implicated in their formation and their evaluation for this purpose requires further osteological research. Compression fractures are linked to age and can be considered poor activity markers, although differences observed in the number of affected

vertebrae suggest that activity plays a role in their development. Spondylolysis, traditionally the best marker among those studied, is present in only six skeletons in these collections and yields information about the individuals; however, this result cannot be extrapolated to the population as a whole because the number of cases is very small.

When the historical background is known, as in the present case, the results are easy to interpret. However, in the absence of reliable information, numerous and equally plausible explanations would be possible for the presence of these signs. With the use of these activity markers, it is only possible to suggest that a given group of individuals carried out sufficiently intense physical activities to exert excessive effort on certain anatomical regions. Historical data remain essential to establish the precise nature of these activities.

In summary, research that uses skeletal diseases as a means of gaining knowledge about the activity patterns of a population should adopt a cautious approach. Meaningful information can only be derived from vertebral lesions in comparisons among populations of the same genetic origin and chronological period with a similar age distribution, and whose activity patterns are known.

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PATOLOGIJE KRALJEŽAKA I OBRASCI DJELOVANJA U DVIJE SREDNJOVJEKOVNE POPULACIJE S IBERSKOG POLUOTOKA

SAŽETAK

Cilj ove studije bio je istražiti korisnost nekoliko tipova patologije kralježaka kao markera u osteološkim populacijama. Sveukupno je ispitano 2165 kralježaka na 124 osobe. Kralješci su sakupljeni iz grobova u dva sela: Villanueva de Soportilla (Burgos, sjeverna Španjolska), sa kršćanskom populacijom, i La Torrecilla (Granada, južna Španjolska), naseljen Muslimanima. Degenerativne bolesti, Schmorlovi defekti, kompresijske frakture i spondiloza sa spondilolistezom analizirani su na osobama i na odvojenim dijelovima kralježaka. Sva patološka stanja, osim kompresijskih fraktura, bila su značajno učestalija kod muškaraca nego kod žena, što ukazuje na intenzivnije radne uvjete za muškarce. Patologije su značajno učestalije među muškarcima iz Villanueve, graničnoj populaciji seljaka vojnika, nego među muškarcima iz La Torrecille. Isto tako, značajno se učestalije patologije pojavljuju među ženama iz kršćanske Villanueve nego u muslimanskoj La Torrecilli, gdje su žene većinom radile kod kuće. Korisnosti i i ograničenja studije patologija kralježaka su raspravljeni u radu.