ANTHROPOLOGIE * XXX/1 * 1992

RIMANTAS JANKAUSKAS

DEGENERATIVE CHANGES OF THE VERTEBRAL COLUMN IN LITHUANIAN PALEOOSTEOLOGICAL MATERIAL

ABSTRACT: The incidence of osteophytes, osteochondrosis, and Schmorl's nodes was investigated on 6,357 vertebrae and 336 sacral bones that belonged to 539 adult persons from the burial grounds dated to the 1st and 2nd millennia A.D. It was estimated that osteophytes and osteochondrosis are highly correlated, and the age factor's influence on their occurrence forms about 30% of the total sum of factors, so the opinion of specialists that they are the particular conjugated manifestations of the universal process of ageing of the intervertebral discs and the vertebral column in general, was confirmed. Factors of sex, living conditions and secular factor have little influence on their occurrence. The significance of the body build features could be found only in females. On the other hand, the degree of development of osteophytes and osteochondrosis have the influence on the measurements of the vertebral column. The conclusion follows that the reliability of osteophytes, osteochondrosis, and Schmorl's nodes, as the markers of the environmental stress, must be revised, and other investigations on other populations living in various ecological conditions must be encouraged.

KEY WORDS: Osteophytes — Osteochondrosis — Schmorl's nodes — Paleopathology — Vertebral column — Lithuania.

INTRODUCTION

Many morphological, roentgenological, biochemical and other data on the occurrence and development of degenerative changes of the vertebral column have been collected recently. Notwithstanding this, some problems seem to remain unsolved. Firstly, the border between physiological (degenerative changes) and pathological (degenerative lesions) remains unclear, it means that the exact influence of the age factor is undetermined. Many investigators (Rokhlin 1940, Kosinskaya 1961, Borisevich 1967, Tager 1983, Podrushniak 1987) have emphasized that degenerative-dystrophic changes, which take place in the intervertebral discs and produce secondary reactions on vertebral bodies, articulations and ligaments are natural manifestations of ageing of the locomotory system. They are universal for all vertebrates (Swinton 1979, Bjorkengren et al. 1987, Clauser 1981, DeRousseau 1985, etc.). Secondly, data on the role of sex and living conditions are controversial. The majority of authors have not found substantial sexual differences. Age-conditioned changes in general, and signs of ageing of the vertebral column in particular, occur earlier in brachyomorphic persons (Nikityuk 1969, Borisevich et al. 1980, Modelkin 1983). Investigations of the epidemiology of osteochondrosis have shown only minimal influence of the geographical factor (Schmidt et al. 1976). There are many investigations of paleoosteological material (Gejvall 1960, Swedborg 1974, Stloukal, Vyhnánek 1976, McWhirr et al. 1982), but they either lack secular comparisons, or conclusions are made on the basis of small samples (Stewart 1966, Lynn 1982, Kramar et al. 1986). So it seems that exploration of the problem of degenerative changes of the spine on paleoosteological material of various ethnoterritorial groups living in different ecological and social conditions may by helpful for better understanding of the above-mentioned

Paper presented at the 3rd Anthropological Congress of Aleš Hrdlička, held on September 3–8, 1989 in Humpolec, Czechoslovakia.

questions. This, in turn, could supplement our knowledge on the biology of ageing processes in general.

The purpose of this investigation was to examine forms, localisation and interrelations of degenerative changes of the vertebral column (spondylosis deformans, osteochondrosis and Schmorl's nodes) on paleo-osteological material from Lithuania, and to trace the influence of the sex, age, period and social factors on their manifestations.

MATERIALS AND METHODS

The investigated material consisted of 6,537 vertebrae and 336 sacral bones that belonged to 539 adult persons from various burial grounds, dated to the 1st and the 2nd millennia A. D. Fifty persons were dated to the 1st millennium, the rest to the 2nd – these were subdivided into 3 social groups: rural cemeteries (98), urban ones (367), and skeletons from the Vilnius Archicathedral (24, males only), representing mostly the high Church officials. The routine osteometry of the long bones and the vertebrae was performed (Martin, Saller 1957). The anterior and posterior height and middle breadth of the vertebral bodies were estimated. The identification of osteophytes was performed with the help of the 3 grade scale, elaborated by I.Swedborg (1974), with references to Stloukal, Vyhnánek (1976). Pommer's nodes and traces of osteosclerosis on the terminal plates were identified as the signs of osteochondrosis. As far as Schmorl's nodes are concerned, two forms (central and dorsal) were noted separately. The statistical elaboration was performed in the Computer center of Vilnius University. Routine packages of programs for statistical analysis BMDP and SAS were used.

RESULTS AND DISCUSSION

Osteophytes

They are the most frequent signs of the degeneration of intervertebral discs, occurring both in *spondylosis deformans* and in osteochondrosis. The combination of these two forms is quite frequent (Tager 1983). Taking into account this, and having no full

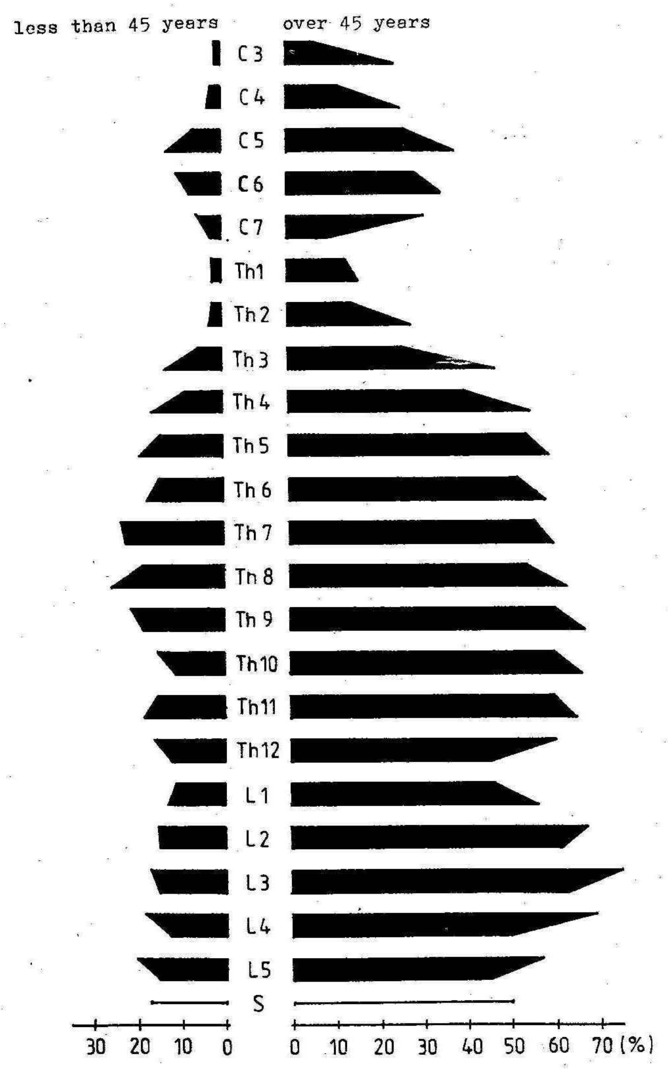

Figure 1. Frequencies of all forms of osteophytes on the male vertebrae in two age groups.

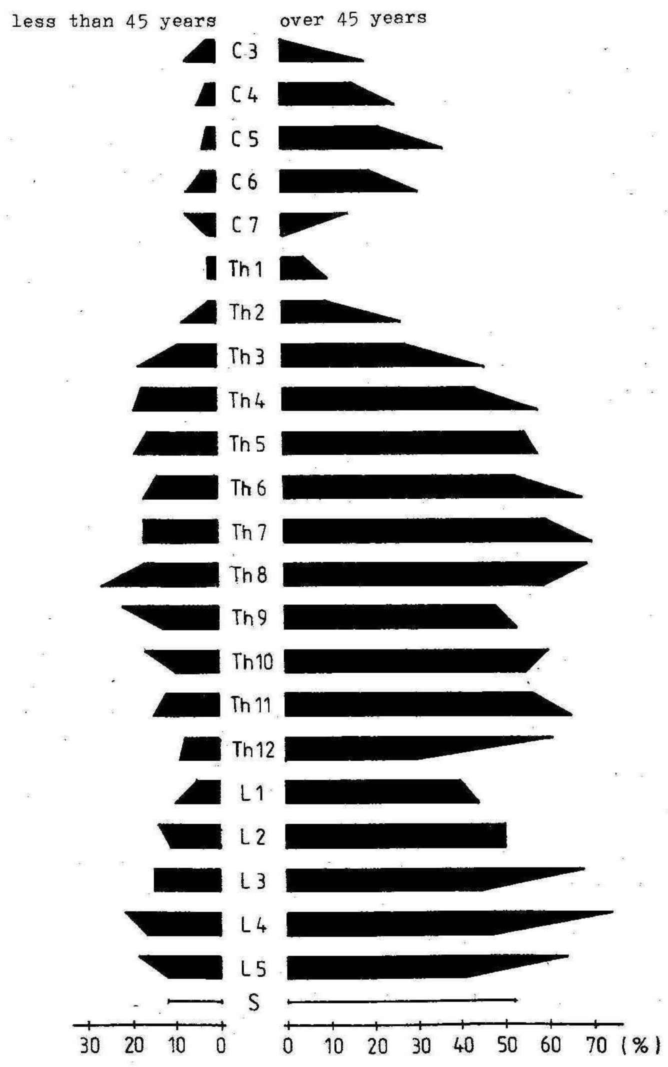

Figure 2. Frequencies of all forms of osteophytes on the female vertebrae in two age groups.

complex of clinical and roentgenological symptoms, we have not aimed at separating disctinctly these two nosological units, and limited ourselves on the simple scoring of the osteophytes. The distribution of the osteophytes in the pooled sample is presented in *Table 1.* For both sexes, these changes manifested most frequently in lumbar, and also in lower and middle thoracic vertebrae. They were considerably less frequent in cervico-thoracic and thoraco-lumbar areas. It should be mentioned that osteophytes appear first, and later are found most frequently and are the biggest on C5 – C6, Th7 – Th9 and L3 – L4, that means on the peaks of the physiological curves of the spine (Merbs 1983). In the pooled sample, they are found more frequently on male skeletons. But comparison of their occurrence in age groups revealed no substantial sex differences (*Figs. 1 and 2).* Age dynamics of the manifestation of the osteophytes is evident. They appear usually at the age of 25–35, and their frequencies increase during life-time. It must be noted that their earliest manifestation occur on the peaks of the physiological curves of the spine. This points out to the greatest loading and wearing and tearing of these regions (Alkhovskij 1937, Borisevich 1967, Tager 1983, Merbs 1983). In both sexes this process is similar, and sexual differences in pooled samples should be explained by the worse demographical situation among females in investigated populations.

Osteochondrosis

In males, as well as in females, signs of osteochondrosis have been found in all regions of the spine (*Table 2, Fig. 3*). These changes were frequent on lumbar, cervical, mid- and lower thoracic vertebrae, but most frequent on the peaks of the physiological curves; the decrease of their manifestation in transitional (cervico-thoracic and thoraco-lumbar) vertebrae was evident. A distinct dependence on the age was noted in both males and females. Sexual differences were not marked, especially in age groups. Only on the lower thoracic area (Th9 – Th12) the incidence of osteochondrosis in males was significantly higher ($p < 0.05$). So it can be concluded that the general regularities of osteochondrosis are the same as in osteophytes: it appears usually in the 3rd decade of life, and its frequencies increase with age, especially after

Table 1. Osteophyte frequencies on male and female vertebrae (%).

Vertebra (superior/ inferior surface)	Males					Females				
	N	Grade 1	Grade 2	Grade 3	Grades 1+2+3	N	Grade 1	Grade 2	Grade 3	Grades 1+2+3
C3	184	3.80	0.00	0.00	3.80	127	1.57	0.00	0.00	1.57
		9.78	1.08	0.00	10.87		10.24	0.00	0.00	10.24
C4	188	4.79	1.60	0.00	6.38	134	5.97	0.00	0.00	5.97
		11.17	2.66	0.00	13.83		9.70	0.75	0.00	10.45
C5	191	14.66	1.57	0.00	16.23	129	6.98	1.55	0.00	8.53
		21.47	3.14	0.00	24.61		12.40	1.55	0.00	13.95
C6	196	16.33	2.55	0.00	18.88	129	7.75	0.77	0.00	8.53
		13.26	5.10	1.02	19.39		12.40	0.55	0.00	13.95
C7	203	13.30	2.46	0.49	16.26	139	8.63	0.72	0.00	9.35
		3.94	0.49	0.00	4.43		1.44	0.00	0.00	1.44
Th1	207	6.28	0.00	0.00	6.28	142	2.82	0.00	0.00	2.82
		7.73	0.48	0.00	8.21		4.22	0.00	0.00	4.22
Th2	212	7.07	0.00	0.00	7.07	138	5.07	0.00	0.00	5.07
		13.68	0.47	0.00	14.15		13.77	0.00	0.00	13.77
Th3	207	14.49	0.00	0.00	14.49	136	15.44	0.00	0.00	15.44
		26.57	1.45	0.48	28.50		25.73	1.47	0.00	27.21
Th4	205	21.46	0.98	0.00	22.44	135	25.18	0.74	0.00	25.93
		31.71	1.46	0.00	33.17		31.85	0.00	0.00	31.85
Th5	200	31.00	0.50	0.50	32.00	132	28.03	0.76	0.00	28.79
		34.50	1.50	0.50	36.50		30.30	0.76	0.00	31.06
Th6	193	29.02	0.52	1.04	30.57	124	25.00	0.80	0.00	25.81
		31.09	2.59	1.55	35.23		31.45	0.81	0.00	32.26
Th7	193	33.16	1.55	1.55	36.27	118	26.27	2.54	0.00	28.81
		31.09	2.59	3.63	37.31		27.12	5.08	0.00	32.20
Th8	195	25.64	3.08	4.10	32.82	117	29.06	3.42	0.00	32.48
		32.31	3.59	5.13	41.03		33.33	1.71	0.85	35.90
Th9	187	31.02	3.21	4.28	38.50	114	27.19	0.88	0.88	28.95
		29.95	4.81	4.81	39.57		21.93	1.75	1.75	25.44
Th10	186	26.88	4.84	3.76	35.48	113	26,55	1.77	2.65	30.97
		25.27	5.91	4.30	35.48		23.01	1.77	0.00	24.78
Th11	183	26.23	6.56	3.82	36.61	109	22.94	1.83	0.00	24.77
		25.68	10.93	3.28	39.89		22.94	4.59	0.00	27.53
Th12	190	29.47	4.74	2.63	36.84	109	19.27	2.75	0.00	22.02
		20.00	5.79	1.05	26.84		11.94	1.83	0.00	13.76
L1	208	19.23	5.77	0.96	25.96	115	12.17	1.74	0.00	13.91
		23.08	8.65	0.96	32.69		18.26	0.87	0.00	19.13
L2	210	22.38	13.81	2.38	38.57	121	18.18	4.96	0.00	23.14
		23.81	9.05	2.38	35.24		19.01	2.48	0.00	21.49
L3	218	23.85	15.14	4.59	43.58	136	22.79	5.15	0.00	27.94
		24.77	9.17	3.21	37.16		18.38	2.94	0.00	21.32
L4	211	21.80	14.69	4.74	41.24	138	25.36	10.14	0.00	35.51
		18.96	6.16	2.84	27.96		22.46	2.17	0.00	24.64
L5	215	25.58	8.84	2.33	36.74	138	25.36	5.07	0.00	30.43
		21.39	4.65	0.93	26.98		17.39	5.07	0.00	22.46
S	232	27.59	3.02	0.00	30.60	163	20.86	3.07	0.00	23.93

Table 2. Osteochondrosis frequencies on male and female vertebrae (%).

Vertebra (superior/ inferior surface)	Males						Females					
	Up to 45 years		Over 45 years		Pooled		Up to 45 years		Over 45 years		Pooled	
	N	P	N	P	N	P	N	P	N	P	N	P
C3	96	0.00	79	2.53	184	1.09	87	0.00	38	0.00	127	0.00
		0.00		6.33		2.72		1.15		2.63		1.57
C4	97	0.00	81	7.41	188	3.19	92	1.08	38	5.26	134	2.24
		0.00		8.64		4.25		0.00		5.26		1.49
C5	98	1.02	81	11.11	191	6.28	86	1.16	40	7.50	129	3.10
		2.04		11.11		7.85		1.16		17.50		6.20
C6	104	2.88	79	15.19	196	9.18	86	1.16	39	10.26	129	3.88
		2.88		20.53		11.22		2.33		17.95		6.98
C7	109	2.75	80	17.50	203	8.87	93	3.23	40	15.00	139	6.47
		0.00		0.00		0.00		2.15		0.00		1.44
Th1	114	0.00	83	2.41	207	0.97	96	2.08	41	2.44	142	2.11
		0.00		1.20		0.48		1.04		2.44		1.41
Th2	115	0.87	86	2.33	212	1.89	91	1.10	40	2.50	138	1.45
		0.00		2.33		0.94		1.10		2.50		1.45
Th3	114	0.00	83	1.20	207	0.48	88	0.00	39	5.13	136	1.47
		0.88		2.41		1.45		1.14		5.13		2.94
Th4	111	0.00	84	3.57	205	1.46	88	1.14	38	5.26	135	2.22
		1.80		8.33		4.39		1.14		10.53		4.44
Th5	110	0.00	79	2.53	200	1.00	86	2.33	36	5.56	132	3.79
		0.00		12.66		5.00		2.33		11.11		5.30
Th6	105	0.00	76	5.26	193	2.07	80	2.50	34	8.82	124	4.03
		0.00		18.42		7.25		1.25		11.76		4.03
Th7	106	1.89	77	7.79	193	4.14	75	1.33	33	9.09	118	3.39
		3.77		18.18		9.33		2.67		16.15		6.78
Th8	106	1.89	78	12.82	195	6.15	75	2.67	32	18.75	117	6.84
		1.89		23.08		10.77		4.00		21.87		8.55
Th9	97	4.12	78	20.51	187	10.69	74	2.70	30	13.33	114	5.26
		1.03		14.10		6.95		2.70		13.33		5.26
Th10	99	2.02	77	15.58	186	8.06	74	1.35	29	10.34	113	3.54
		7.07		15.58		11.29		1.35		6.90		2.65
Th11	95	5.26	78	10.57	183	7.10	72	0.00	28	7.14	109	3.67
		6.32		21.79		13.11		2.78		14.29		5.50
Th12	101	5.94	78	16.67	190	10.00	73	1.37	28	7.14	109	3.67
		5.94		11.54		8.95		1.37		3.57		2.75
L1	108	1.85	85	5.88	208	4.33	79	0.00	30	6.67	115	1.74
		4.63		7.06		5.77		1.27		13.33		4.35
L2	109	4.59	85	10.59	210	7.62	79	3.80	32	15.62	121	6.61
		4.59		8.23		6.67		2,53		6.25		3.31
L3	111	7.21	91	14.29	218	10.55	91	4.40	33	12.12	136	5.88
		1.80		9.89		5.96		2.20		6.06		2.94
L4	114	3.51	82	14.63	211	8.53	90	5.56	36	19.44	138	8.70
		2.63		12.19		7.11		1.11		13.89		4.35
L5	115	6.09	84	20.24	215	12.56	93	4.30	33	21.21	138	7.97
		4.35		13.09		8.37		6.45		30.30		12.32
S	118	5.08	90	16.67	232	10.34	110	8.18	42	19.05	163	11.66

the 5th decade; the earliest manifestation was on the peaks of the physiological curves, where the highest incidence is later observed; low frequencies are in transitional areas of the vertebral column.

Schmorl's nodes

In the material investigated they were absent on cervical vertebrae. Only solitary nodes were found on the upper thoracic vertebrae (Th1 – Th4). Schmorl's nodes appeared most frequently on the middle thoracic vertebrae (*Table 3, Fig. 4*). On the male vertebrae, only single nodes were found in the lower lumbar region, and in females they were absent on the 3rd and lower lumbar vertebrae. The dorsal nodes were noted mainly in the thoracic region, more frequently on the lower surfaces of the vertebral bodies. Sexual differences in general were only minor, only in the lumbar region in males, frequencies were significantly higher ($p<0.01$). The absence of age dynamics in the occurrence of Schmorl's nodes is evident. They were found at the age of less than 25 years, their frequencies slightly increased during the next decade (25 – 35 years), and remained constant or even slightly decreased in subsequent age groups. So the following characteristics can be traced on the manifestation of Schmorl's nodes: they appear usually at the age before 35 years, mainly on the mid- and lower thoracic vertebrae. Dorsal nodes, which are found more frequently on the lower surfaces of thoracic vertebrae,

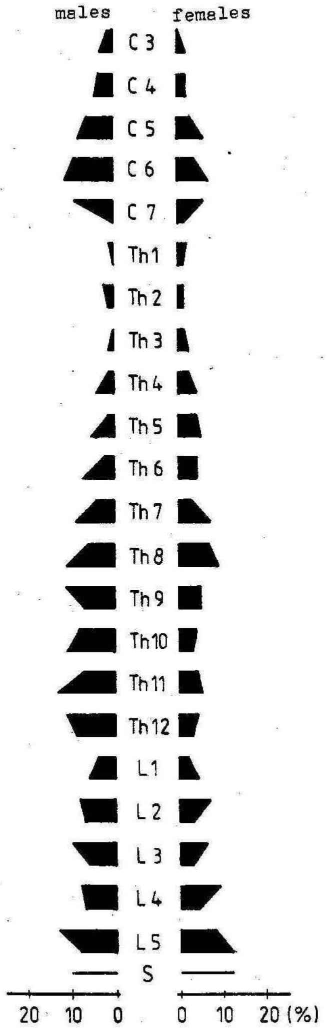

Figure 3. Osteochondrosis frequencies on male and female vertebrae.

could be explained by the presence of the rudimental *lig. intraarticulare capitis costae* that is tightly connected with intervertebral discs in the ontogenesis (Lohse et al. 1985). In males, Schmorl's nodes appear in a more expanded region than in females. Age dynamics are not characteristic of Schmorl's nodes. These characteristics possibly document different mechanisms of emergence than in the case of osteophytes and osteochondrosis.

For more grounded conclusions on the regularities of manifestation of the degenerative changes of the vertebral column, a statistical analysis of interrelations between osteophytes, osteochondrosis and Schmorl's nodes was performed. The correlation analysis revealed the presence of significant relationship (at the level of 0.3 – 0.4) between osteophytes and osteochondrosis. The highest correlations were found between these two forms in the region of the same intervertebral disc, which points out to the similarity of the causative factors. On the other hand, correlations between osteophytes and Schmorl's nodes were insignificant, and in many cases had the tendency of negative relations.

A more general and synthetic notion on the interrelations between these three investigated forms of degenerative changes can be formed by examining correlations between the regions of the vertebral column (*Table 4*). It was estimated that osteophytes in all regions have strong significant correlations (r = 0.5 – 0.8). Slightly lower, but also significant, correlations (r = 0.4 – 0.5) between osteochondrotic changes do exist. Relations between Schmorl's nodes are weaker (r = 0.3), although significant. Osteophytes also significantly correlate with osteochondrosis. The absence of correlations between these two forms and Schmorl's nodes is evident. Cluster analysis (*Fig. 5*) finally elucidated the interrelations between osteophytes, osteochondrosis and Schmorl's nodes. One big cluster is formed from the osteophyte (1., 2., 3., 4., 5.) and osteochondrosis (6., 7., 8., 9., 10.) subclusters. Schmorl's nodes form a separate cluster.

In case of the explanation of factors which could have an influence on the emergence of the degenerative changes of the spine, the impact of sex, age, secular and social factors were evaluated. Dispersion analysis has proven (*Table 5*) that the sex factor has in most cases no significant influence on the manifestation of the features investigated. The age factor's influence is in most cases highly significant ($p<0.001$) for osteophytes and osteochondrosis. It must be noted that the greatest age dynamics were estimated in those regions, where degenerative changes occur most early, are observed most frequently and are the most marked (lumbar and lower thoracic segments for osteophytes, lumbar and cervical regions for osteochondrosis). The age factor has no influence on the manifestation of Schmorl's nodes. The secular factor plays practically no significant role on the occurrence of all forms of degenerative changes.

An attempt was made to evaluate the impact of the social factor on the degenerative changes of the vertebral column. For this purpose, two groups of male skeletons (from rural cemeteries and from the Vilnius Archicathedral) were compared (*Table 6*). In both groups similar general regularities were noted: the highest frequencies of osteophytes were found on the mid- and lower thoracic and lumbar vertebrae, osteochondrosis – on the cervical, midthoracic and lumbar, Schmorl's nodes with the same frequencies – on the mid- and lower thoracic vertebrae. Frequencies of osteophytes and osteochondrosis were higher ($p<0.05$) in rural cemeteries. The cause of this difference could be in the different demographical structure of the investigated groups: the average age at death in the rural sample was 43.55 years, and in the Vilnius Archicathedral sample 37.19 years. This could explain the differences in age-conditioned changes (osteophytes and osteochondrosis) and the absence of differences in Schmorl's nodes which are not age-dependent.

The comparison of our data with the results of other investigations of paleopopulations (Swedborg 1974, Stloukal, Vyhnánek 1976, Merbs 1983, Kelley 1982, Saluja et al. 1986) as well as of roentgenological screening of living persons (Kosinskaya 1966, Klioner 1962, Mikhailovsky 1963, Reinberg 1964, Borisevich 1971, Tager, Dyachenko 1971, Resnick, Niwayama 1978) revealed no major differences. It means that maybe at least in some publications genetic and environmental factors influencing the degenerative changes of the vertebral column are overestimated.

In conclusion, it could be said that the statistical analysis enabled us to separate distinctly different forms of the degenerative changes, on the basis of which different biochemical and morphological processes lie.

During ageing, dehydration and mineralisation of the intervertebral discs, swelling and desorganisation of

Table 3. Schmorl's nodes frequencies on male and female vertebrae.

Vertebra (superior/ inferior surface)	Males				Females			
	N	Central	Dorsal	Pooled	N	Central	Dorsal	Pooled
Th1	207	0.00	0.00	0.00	142	0.00	0.00	0.00
		0.48	0.00	0.48		0.00	0.00	0.00
Th2	212	0.00	0.00	0.00	138	0.00	0.00	0.00
		0.00	0.00	0.00		0.00	0.00	0.00
Th3	207	0.48	0.48	0.97	136	0.00	0.00	0.00
		0.00	0.00	0.00		0.73	0.00	0.73
Th4	205	0.98	0.00	0.98	135	0.00	0.00	0.00
		0.00	2.44	2.44		0.00	0.00	0.00
Th5	200	0.00	2.50	2.50	132	0.00	0.00	0.00
		4.50	3.00	7.50		4.54	0.76	5.30
Th6	198	0.00	2.59	2.59	124	0.81	1.61	2.42
		5.70	6.22	11.92		8.06	4.03	12.10
Th7	193	0.52	4.66	5.18	118	0.00	1.69	1.69
		8.29	9.84	18.13		9.32	4.24	13.56
Th8	195	0.51	5.13	5.64	117	0.00	8.55	8.55
		9.23	5.64	14.87		9.40	3.42	12.82
Th9	187	0.00	5.88	5.88	114	0.00	1.75	1.75
		5.35	6.95	12.30		7.89	1.75	9.65
Th10	186	0.00	4.84	4.84	113	0.00	2.65	2.65
		2.68	3.23	5.91		6.19	2.65	8.85
Th11	183	0.55	5.46	6.01	109	0.92	2.75	3.67
		1.09	6.02	7.10		1.83	2.75	4.59
Th12	190	0.00	5.79	5.79	109	0.92	2.75	3.67
		0.00	4.74	4.74		0.00	1.83	1.83
L1	208	0.48	4.81	5.29	115	0.00	2.61	2.61
		0.48	1.92	2.40		0.00	0.87	0.87
L2	210	0.00	2.86	2.86	121	0.00	0.83	0.83
		0.95	0.95	1.90		0.00	0.00	0.00
L3	218	0.00	2.75	2.75	136	0.00	0.00	0.00
		0.00	1.38	1.38		0.00	0.00	0.00
L4	211	0.00	0.95	0.95	138	0.00	0.00	0.00
		0.00	0.47	0.47		0.00	0.00	0.00
L5	215	0.46	0.46	0.93	138	0.00	0.00	0.00
		0.46	0.00	0.46		0.00	0.00	0.00
S	232	0.00	0.00	0.00	163	0.00	0.00	0.00

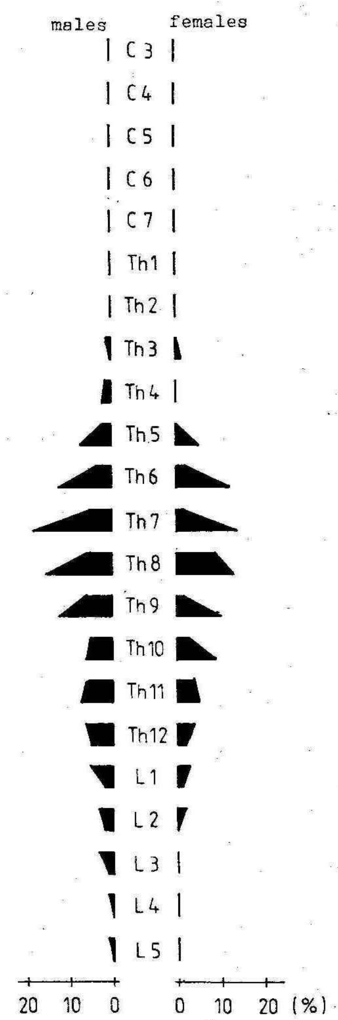

Figure 4. Frequencies of all forms of Schmorl's nodes on the male and female vertebrae.

Table 4. Correlation coefficients between the degenerative changes of the regions of the vertebral column.

N	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
2.	.578***												
3.	.567***	.392***											
4.	.297***	.293***	.372***										
5.	.029	.006	.001	.041									
6.	.547***	.391***	.805***	.287***	.019								
7.	.393***	.501***	.449***	.415***	.155*	.474***							
8.	.089	.160*	.120	.087	.326***	.155**	.177**						
9.	.568***	.470***	.710***	.325***	.068	.817***	.498***	.188**					
10.	.437***	.468***	.525***	.430***	.091	.554***	.666***	.207**	.551***				
11.	.078	.111	.150*	.048	.314***	.157*	.172*	.594***	.164**	.169**			
12.	.557***	.397***	.648***	.320***	-.004	.711***	.417***	–.034	.763***	.511***	–.003		
13.	.390***	.436***	.542***	.403***	-.060	.546***	.539***	.035	.548***	.667***	.005	.637***	
14.	.141	.105	.077	.011	.127	.034	.178*	.313***	-.004	.165*	.374***	.023	.075

** – $p < 0.05$; ** – $p < 0.01$; *** – $p < 0.001$*

1. Cervical osteophytes; 2. Cervical osteochondrosis; 3. Upper thoracic (Th1 – Th4) osteophytes; 4. Upper thoracic osteochondrosis; 5. Upper thoracic Schmorl's nodes; 6. Middle Thoracic (Th5 – Th8) osteophytes; 7. Middle thoracic osteochondrosis; 8. Middle thoracic Schmorl's nodes; 9. Lower thoracic (Th9 – Th12) osteophytes; 10. Lower thoracic osteochondrosis; 11. Lower thoracic Schmorl's nodes; 12. Lumbar osteophytes; 13. Lumbar osteochondrosis; 14. Lumbar Schmorl's nodes.

collagen fibrils, degeneration of the cell elements take place (Podorozhnaya 1976, Sak et al. 1976, Happey et al. 1974, Semionova et al. 1979, Trout et al. 1984), as well as diminution of the disc elasticity, decrease and irregular distribution of its internal pressure (Tsivyan, Raikhinshtein 1975). Such changes of biochemical properties provoke the reaction of the organism – partial ossification of the *annulus fibrosus* and osteophyte formation (Shah et al. 1976, Duncan 1987). At the same time, dystrophic changes of the terminal hyaline plates take place: foci of the fibrous cartilage emerge, blood vessels grow in, foci of osteogenesis, atrophy and sclerosis of subchondral bone appear, distinguishable also on macerated material (Tsivyan, Zaidman 1976). So osteophyte formation and osteochondrosis in most cases are the consequences of the one process of age-conditioned involution, „discopathy". That is why the combination of these two forms is not rare (Tager 1983). It seems that it is not completely excluded to consider spondylosis deformans (osteophytosis) and osteochondrosis as two different manifestations of the same process: the first one – „light degree of partial intervertebral osteochondrosis" (the process is localised mainly in the annulus fibrosus and the anterior longitudinal ligament), and the second one – „heavy degree of total intervertebral osteochondrosis" (primary changes of the *nucleus pulposus* and terminal plates – Klioner 1962). It must be taken into account that the ongoing process involves also other elements of the disc.

Another mechanism lies in the emergence of Schmorl's nodes. When the biochemistry and the internal pressure of the intervertebral disc remain unchanged (Pearson et al. 1974), local disruption under pressure of the *annulus fibrosus* or desintegration of the hyaline plate takes place, into which part of the *nucleus pulposus* falls. The formation of the osseous layer around the hernia is finished by consequent

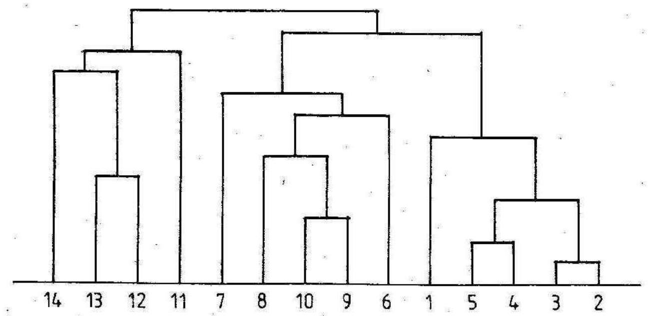

Figure 5. Clusterisation of the correlation matrix of the degenerative changes on the regions of the vertebral column (by the method of the main component analysis). 1. – cervical osteophytes; 2., 3., 4. – osteophytes of the superior, middle and inferior thoracic segments; 5. – lumbar osteophytes; 6. – cervical osteochondrosis; 7., 8., 9. – osteochondrosis of the superior, middle and inferior thoracic segments; 10. – lumbar osteochondrosis; 11., 12., 13. – Schmorl's nodes on the superior, middle and inferior thoracic segments; 14. – lumbar Schmorl's nodes.

Table 5. The influence (η_x^2 %) of the factors of variability of degenerative changes.

Feature	Sex	Age	Period
Cervical region (C3 – C7):			
Osteophytes	1.31	18.14***	0.05
Osteochondrosis	0.58	10.89***	1.34
Upper thoracic segment (Th1 – Th4):			
Osteophytes	0.07	18.58***	0.18
Osteochondrosis	0.79	2.70	0.12
Schmorl's nodes	1.10	0.80	2.90*
Middle thoracic segment (Th5 – Th8):			
Osteophytes	0.15	25.34***	0.01
Osteochondrosis	0.03	11.72***	0.19
Schmorl's nodes	0.10	1.71	0.50
Lower thoracic segment (Th9 – Th12):			
Osteophytes	1.89*	32.59***	0.13
Osteochondrosis	2.01*	8.52***	0.40
Schmorl's nodes	0.09	2.28	0.02
Thoracic region (Th1 – Th12):			
Osteophytes	1.16	29.50***	0.14
Osteochondrosis	0.73	12.81***	0.35
Schmorl's nodes	0.17	3.15	0.15
Lumbar region (L1 – L5):			
Osteophytes	2.09*	37.48***	0.00
Osteochondrosis	0.22	10.57***	0.72
Schmorl's nodes	2.00*	1.10	0.09
Total vertebral column (C3 – L5):			
Osteophytes	1.39	37.75***	0.05
Osteochondrosis	0.18	16.09***	0.00
Schmorl's nodes	0.27	6.92	0.04

** – $p < 0.05$; ** – $p < 0.01$; *** – $p < 0.001$*

Table 6. Frequencies of the degenerative changes of vertebrae in two male samples.

Feature	Rural Cemeteries		Vilnius Archicathedral	
	N	P	N	P
Cervical region (C3 – C7):				
Osteophytes	292	7.53	164	6.10
Osteochondrosis	292	3.42	164	1.83
Upper thoracic segment (Th1 – Th4):				
Osteophytes	222	12.61	168	6.55
Osteochondrosis	222	2.25	168	0.00
Schmorl's nodes	222	0.90	168	0.59
Middle thoracic segment (Th5 – Th8):				
Osteophytes	212	27.36	162	19.75
Osteochondrosis	212	6.13	162	1.85
Schmorl's nodes	212	14.62	162	8.64
Lower thoracic segment (Th9 – Th12):				
Osteophytes	234	28.20	160	13.12
Osteochondrosis	234	1.28	160	0.62
Schmorl's nodes	234	7.26	160	10.00
Thoracic region (Th1 – Th12):				
Osteophytes	668	22.75	490	13.06
Osteochondrosis	668	3.14	490	0.82
Schmorl's nodes	668	7.48	490	6.33
Lumbar region (L1 – L5):				
Osteophytes	428	26.40	210	14.29
Osteochondrosis	428	5.14	210	0.00
Schmorl's nodes	428	3.04	210	5.24
Total vertebral column (C3 – L5):				
Osteophytes	1388	20.68	864	12.04
Osteochondrosis	1388	3.82	864	0.81
Schmorl's nodes	1388	4.54	864	4.86

osteosclerosis. So the Schmorl's node can emerge only when marked degenerative changes in the intervertebral disc are absent. This explains the absence of the age dynamics and the absence of correlations with osteophytes and osteochondrosis in the investigated material. That is why it seems correct to divide osteochondrosis (in the broad sense) into stable (corresponding to Schmorl's nodes) and unstable („true" osteochondrosis) forms, that is on the limit of pathology (Korzh et al. 1980).

Thus, on the basis of this investigation it could be stated that different biochemical and histomorphological changes that take place in the intervertebral discs, leave different traces on the morphology of the vertebrae. One group are the age conditioned degenerative changes of the intervertebral discs (osteochondrosis in the narrow sense) that cause an impairment of the static and dynamic functions of the spine („unstable" form) and, as the consequent adaptive reaction of the organism – osteophyte formation, as „the light degree of partial intervertebral osteochondrosis" that is very often observed in advanced age. Changes in the terminal plates – „the heavy degree of total intervertebral osteochondrosis", approach the degenerative lesion (pathology) of the spine. The common general characteristics, revealed in this work, prove once more the similarity of these two forms of degeneration. In this common process we were unable to trace neither sexual, nor secular, nor social differences; the comparison with data from literature seems to support our opinion. These age-conditioned changes are universal and, except for pathological cases, rarely proceed in isolation: comparatively high correlations were estimated between different segments and regions of the vertebral column. This also proves morphological and functional interdependence – the spine is functioning as a single unit.

Another group are intervertebral discs herniations (Schmorl's nodes). Their manifestation is possible only when marked involutionary changes (diminution of the intra-disc pressure) are absent. The disc compression leads to local rupture of the *annulus fibrosus* or intrusion of the *nucleus pulposus* into the vertebral body. The static and dynamic characteristics of the spine in this case are not impaired sufficiently („stable" form of osteochondrosis).

An attempt was also made to evaluate the influence of the body build features, as well as the metric characteristics of the vertebral column on the incidence of the degenerative changes. The correlation analysis has shown (*Tables 7* and *8*) that in males correlations between osteophytes, osteochondrosis and Schmorl's nodes, and the reconstructed indices of physical development (discussed elsewhere) are insignificant. In females, other regularities have been unveiled: many correlation coefficients show the incidence of significant relations of average degree between majority of somatometric indices and the age-conditioned degenerative changes. It means that at least in females the somatological factor has some influence on the above-mentioned changes: the larger body measurements predispose the increase of the osteophyte and the osteochondrosis frequencies.

The correlation coefficients between the changes investigated and the measurements of the vertebral column are presented in *Table 9*. Both in males and in females anterior height of the vertebrae in general is little connected with the degenerative changes, although

Table 7. Correlation coefficients between the degenerative changes and the indices of body build in males.

Index	Osteophytes	Osteochondrosis	Schmorl's nodes
Body length	–.050	.017	.097
Body weight	.175	.223	.086
Shoulder breadth	.010	.076	–.219
Biospinal pelvis breadth	.54	–.014	.143
Biocristal pelvis breadth	–.067	–.076	.245*

$* - p < 0,05$

Table 8. Correlation coefficients between the degenerative changes and the indices of body build in females.

Index	Osteophytes	Osteochondrosis	Schmorl's nodes
Body length	.300	.508**	–.096
Body weight	.451*	.304	.339
Shoulder breadth	.365	.405*	.031
Biospinal pelvis breadth	.554*	.439*	–.041
Biocristal pelvis breadth	.193	.189	.114

$* - p < 0.05$; $** - p < 0.01$

some tendency to negative relations with the osteophytes and the osteochondrosis is evident. At the same time, there are practically no correlations between all three forms of degeneration and posterior height. The middle width of the vertebrae is very often significantly positively connected with the age-conditioned changes. The same tendency in relations exists between investigated changes and the sagittal index. It seems that these regularities are the reflection of the influence of the age-conditioned changes on the measurements of the vertebrae. During the development of the osteophytes, the ossification of the anterior longitudinal ligament that performs the functions of the periosteum of the vertebral body, takes place, and its breadth increases. It is quite possible that during ageing due to greater loading the anterior height of the vertebral body decreases, although dispersion analysis has not revealed significant influence of the age factor on this index. Other investigators (Ericksen 1978, Twomey et al. 1983) have come to similar conclusions. We would speculate that in the case of another age structure of the sample (in ours young persons prevail) these tendencies could be more marked.

CONCLUSION

The investigation of the Lithuanian paleo-osteological material and the analysis of the literature data enable us to draw these conclusions: in the popu-

Table 9. Correlation coefficients between the degenerative changes and the measurements of the vertebral column.

Index	Males			Females		
	Steophytes	Osteochondrosis	Schmorl's nodes	Osteophytes	Osteochondrosis	Schmorl's nodes
Cervical region (C3 – C7):						
Anterior height	–.024	–.068	.000	.038	.095	.000
Posterior height	.074	.018	.000	.112	.121	.000
Middle breadth	.201*	.187*	.000	.325**	.242	.000
Sagittal index	.111	.118	.000	.123	.029	.000
Thoracic region (Th1 – Th12):						
Anterior height	–.175	–.071	.098	.166	.056	–.018
Posterior height	–.089	.008	.238*	.000	–.066	.067
Middle breadth	.156	.337**	.328**	.180	.070	.149
Sagittal index	.063	–.037	.308*	–.037	.295	.230
Lumbar region (L1 – L5):						
Anterior height	–.198*	–.053	.012	–.258*	–.235	.000
Posterior height	–.016	.088	–.005	–.003	.019	.000
Middle breadth	.320***	.233**	–.005	.175	.204	.000
Sagittal index	.223	.176	–.027	.427**	.363**	.000
Total vertebral column (C3 – L5):						
Anterior height	–.136	.130	.147	.327	.238	.164
Posterior height	.037	.148	.168	–.114	–.317	–.101
Middle breadth	.184	.220	.353**	.288	–.077	.023
Sagittal index	.192	.222	.314*	–.151	.023	–.244

$* - p < 0.05$; $** - p < 0.01$; $*** - p < 0.001$.

lation, osteophytes and osteochondrosis are particular conjugated manifestations of one universal process of the ageing of the intervertebral discs and the vertebral column in general – the age factor's influence form in the average 30% and more from the sum of all factors. Topographic and functional conditions of a particular disc, segment and region have the main influence on the pecularities of manifestation of these changes: they occur most early, and later are most marked on the peaks of the physiological curves of the spine. As much as can be considered from our material and statistical analysis, sex, living conditions and the secular factor have little influence on this process. Body build features also have little influence on the incidence of the age-conditioned changes: the bigger body measurements only slightly correlate with osteophytes and osteochondrosis, and only in females. On the other hand, age-conditioned changes of the spine have an influence on the measurements of the vertebral column: the development of osteophytes and osteochondrosis cause an increase of the vertebral body breadth and, probably, some decrease of the anterior height.

Schmorl's nodes are not the consequence of the ageing of the vertebral column. It seems that morphological pecularities of the disc and biochemical factors play the major role in their manifestation. Only minor sexual differences in the lower spine were found. Secular and social factors have no influence on the manifestation of Schmorl's nodes in our material.

Thus, it seems that the etiology of the degenerative changes of the vertebral column is rather complicated and one must avoid the simplification while explaining them simply as the consequence of biomechanical stress. We should consider that the reliability of osteophytes, osteochondrosis, and Schmorl's nodes, as the markers of environmental stress, must be reevaluated. It means that other investigations on other populations, living in various and contrasting conditions, are welcomed.

ACKNOWLEDGEMENT

The author would like to express his appreciation to Drs. N.Kosareva and D. Krapavickaite from the Vilnius University Computer Centre for the statistical elaboration of the material.

REFERENCES

ALKHOVSKIJ M. E., 1937: Proyavlenia starenia i nekotorye konstitutsionalnye osobennosti v poyasnitchno-krestsovom otdele pozvonotchnika. *Vestn. rentgenol. radiol.*, 18, 2: 113 – 124.

BJORKENGREN A. G. et al., 1987: Patterns of paravertebral ossification in the prehistoric saber-toothed cat. *Amer. J. Roentgen.*, 148: 779 – 782.

BORISEVITCH A. I., 1967: *Anatomitcheskie i rentgenologitcheskie osobennosti pozvonotchnogo stolba tcheloveka v vozrastnom aspekte i ikh praktitcheskoe znatchenie.* Avtoref. dis. dokt. med. nauk. Leningrad. 24 pp.

BORISEVITCH A. I., 1971: Kompensatorno-adaptivnye protsessy v startcheskom vozraste na primere pozvonotchnika. In: *Adaptatsia tcheloveka i zhivotnykh v norme i patologii.* Pp. 61 – 65. Jaroslavl, Jarosl. ped. inst.

BORISEVITCH A. I., GLEBOVA I.N., RYZHKOVA G.V., 1980: Kolitchestvennaya otsenka chporoobrazovania na urovne cheinykh, grudnykh i poyasnitchnykh pozvonkov na razlitchnykh etapach ontogeneza. In: *Zakonomernosti morfogeneza opornykh struktur pozvonotchnika na razlitchnykh etapakh ontogeneza.* Pp. 5 – 20. Jaroslavl, Jarosl. gos. un-t.

DE ROUSSEAU C. J., 1985: Aging in the musculoskeletal system of Rhesus monkeys: II. Degenerative joint disease. *Amer. J. Phys. Anthrop.*, 67: 177 – 184.

DUNCAN H., 1987: Bone response to injury/inflammation. *Papers on paleopathology, presented at the*

14th annual meeting, Paleopath. Assoc. Pp. 6 – 7. New York.
ERICKSEN M.F., 1978: Aging in the lumbar spine. II. L1 and L2. *Amer. J. Phys. Anthrop.*, 48: 241 – 246.
ERICKSEN M.F., 1978: Ageing in the lumbar spine. III. L5. *Amer. J. Phys. Anthrop.*, 48: 247 – 250.
GEJVALL N. G., 1960: *Westerhuis. Medieval population and church in the light of skeletal remains.* Hakan Ohlsson, Lund. 212 p.
HAPPEY F. et al., 1974: Variations in the diameter of sollagen fibrils, bound hexose and associated glycoproteins in the intervertebral disc. In: *Connective Tissues. Biochemistry and Patho-Physiology*. Pp. 67 – 70. Berlin e.a.
KELLEY M. A., 1982: Intervertebral osteochondrosis in ancient and modern populations. *Amer. J. Phys. Anthrop.*, 59: 271 – 281.
KLIONER I. L., 1962: *Startcheskie i degenerativnye izmenenia v sustavakh i pozvonotchnike.* Medgiz, Moskva. 151 pp.
KOSINSKAYA N. S., 1966: *Degenerativno-distrofitcheskie porajenia kostnosustavnogo apparata.* Medicina, Leningrad. 195 pp.
KORZH A. A. et al., 1980: Nekotorye voprosy patogeneza i obosnovanie sposobov letchenia osteokhondroza poyasnitchnogo otdela pozvonotchnika. In: *Sovremennye printsipy letchenia degenerativno-distrofitcheskikh zabolevaniy pozvonotchnika.* Pp. 3 – 7. Moskva, Centr. inst. Usoversh. vratchei.
KRAMAR C., LAGIER R., BAUD C.- A., 1986: Comparative study of bone and joint pathology in ancient populations in Switzerland. *Papers on paleopathology, presented at the 6th European members meeting, Paleopath. Assoc.* P. 8. Madrid.
LOHSE C. L., HYDE D. M., BENSON D. R., 1985: Comparative development of thoracic intervertebral discs and intra-articular ligaments in the human, monkey, mouse and cat. *Acta Anat.* (Basel), 122: 220 – 228.
LYNN K., 1982: Vertebral osteophytosis in medieval Nubian population from Kulubnarti, Republic of Sudan. *Amer. J. Phys. Anthrop.*, 57: 202.
MARTIN R., SALLER K., 1957: *Lehrbuch der Anthropologie im systematischer Darstellung.* Bd. 1. G. Fischer Verlag, Stuttgart. 661 S.
MCWHIRR A., VINNER L., WELLS C., 1982. *Romano-British cemeteries at Cirencester excavation committee*. 220 pp.
MERBS C. F., 1983: *Patterns of activity-induced pathology in a Canadian Inuit Population.* Ottawa. 199 pp. (Archeological survey of Canada; Paper N. 119).
MIKHALOVSKIY B. G., 1963: *Rentgenodiagnostika zabolevaniy pozvonotchnika.* Medgiz. Moskva. 260 pp.
MODELKIN A. P., 1983: Morfologia mezhpozvonotchnykh otverstiy pri degenerativnykh processakh v pozvonotchnike (poyasnitchnyi otdel). In: *Zakonomernosti morfogeneza opornykh struktur pozvonotchnika i konetchnostei na razlitchnykh etapakh ontogeneza*. pp. 52 – 63. Jaroslavl, Jarosl. gos. un-t.
NIKITYUK B. A., 1969: *Starenie skeleta i nekotorye faktory iego reguliruyushtchie.* Avtoref. dis. dokt. med. nauk. Moskva. 36 pp.
PEARSON C. H. et al., 1974: Lysosomal enzymes and proteoglycam degradation in the human intervertebral disc. In: *Connective Tissues. Biochemistry and Pathophysiology.* Pp. 158 – 165. Berlin e.a.
PODOROZHNAYA V. T., 1976: Arkhitektonika elastitcheskikh volokon v mezhpozvonkovom diske v vozrastnom aspekte. In: *Aktualnye voprosy patologii pozvonotchnika.* Pp. 25 – 27. Novossibirsk. Inst. citologii i genetiki.
PODRUSHNIAK E. P., 1987: *Vozrastnye izmeneniya i zabolevaniya oporno-dvigatelnogo apparata tcheloveka.* Zdorovia, Kiev. 301 pp.
REINBERG S. A., 1964: *Rentgenodiagnostika zabolevaniy kostei i sustavov.* Vol. 2. Medicina, Moskva. 572 pp.
RESNICK D., NIWAYAMA G., 1978: Intervertebral disc herniations: cartilaginous (Schmorl's) nodes. *Radiology*, 126: 57 – 65.
ROKHLIN D. G., 1940: *Rentgenodiagnostika zabolevanij sustavov.* Leningrad, Inst. OZD i P. 235 pp.
SAK N. N., DEDUKH N. V., KERN M., 1976: Gistokhimitcheskiy i topo-optitcheskiy analiz makromolekuliarnykh strukturnykh izmeneniy osnovnogo viechtchestva mezhpozvonotchnykh diskov tcheloveka. In: *Aktualnye voprosy patologii pozvonotchnika.* Pp. 22 – 24. Novossibirsk, Inst. citologii i genetiki.
SALUJA G. et al., 1986: Schmorl's nodes (intravertebral herniations of intervertebral disc tissue) in two historic British populations. *J. Anat.*, 145: 87 – 96.
SCHMIDT I. R. et al., 1976: Epidemiologia i geografia osteochondroza. In: *Aktualnye voprosy patologii pozvonotchnika.* Pp. 50 – 52. Novossibirsk, Inst. citologii i genetiki.
SEMINOVA G. A., 1983: Sravnitelnaya kharakteristika mikrostruktury mezhpozvonkovykh diskov tcheloveka i nekotorykh zhivotnykh v razlitchnye vozrastnye periody. In: *Zakonomernosti morfogeneza opornykh struktur pozvonotchnika i konetchnostei na razlitchnykh etapakh ontogeneza.* Pp. 21 – 30. Jaroslavl, Jarosl. gos. un-t.
SHAH J. S. et al., 1976: Surface strain distribution in isolated single lumbar vertebrae. *Ann. Rheum. Dis.*, 35: 51 – 55.
STEWART T. D., 1966: Some problems in human palaeopathology. In: Jarcho S. (Ed.): *Human Palaeopathology.* Pp. 43 – 55. Yale University Press, New Haven, London.
STLOUKAL M., VYHNÁNEK L., 1976: *Slované z velkomoravských Mikulčic.* Academia, Praha. 207 pp.
SWEDBORG I., 1974: *Degenerative changes of the human spine – a study on dried macerated skeletons.* Stockholm. 197 pp.
SWINTON W. E., 1979: Animal palaeopathology: its relation to ancient human disease. In: *Disease in Ancient Man.* Ed. G. D. Hart. Pp. 50 – 58. Clarke Irwin, Toronto.
TAGER I. L., DYACHENKO V. A., 1971: *Rentgenodiagnostika zabolevaniy pozvonotchnika.* Medicina, Moskva. 344 pp.
TAGER I. L., 1983: *Rentgenodiagnostika zabolevaniy pozvonotchnika.* Medicina, Moskva. 208 pp.
TROUT J. J. et al., 1982: Ultrastructure of the human intervertebral disc: I. Changes in notochordal cells with age. *Tissue Cell*, 14: 359 – 369.
TSIVYAN I. L., RAIKHINSHTEIN V. E., 1975: Uprugye svoistva pulpoznogo iadra mezhpozvonkovykh diskov po dannym izmerenia vnutridiskovogo davlenia v eksperimente i klinike. In: *Biomekhanika: profilaktika, patogenez i letchenije travm i ortopeditcheskikh deformaciy.* Pp. 60 – 63.
TSIVYAN I. L., ZAIDMAN A. M., 1976: Gistopatologia tkanevykh struktur pri mezhpozvonkovom osteokhondroze. In: *Aktualnye voprosy patologyi pozvonotchnika.* Pp. 27 – 30. Novossibirsk, Inst. tsitologii i genetiki.
TWOMEY L., TAYLOR J., FURNISS B., 1983: Age changes in the bone density and structure of the lumbar vertebral column. *J. Anat.*, 136: 15 – 25.

Dr. Rimantas Jankauskas
Dept. of Anat. Histol. Anthropol.
Faculty of Medicine
Vilnius University
Tchiurlionio 21
2009 Vilnius
LITHUANIA