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VARIATIONS AND ANOMALIES OF THE VERTEBRAL COLUMN IN LITHUANIAN PALAEOOSTEOLOGICAL SAMPLES

ABSTRACT: Skeletons of 857 adult individuals from various selected samples were examined and detected variations and anomalies of the vertebral column were classified either as ontogenetic, phylogenetic or of mixed origin. The conclusion was made that ontogenetic and phylogenetic variations are definitely different types of individual variability. While ontogenetic variations (of vertebral bodies and arches) are not interrelated, age, sex and body build dependent peculiarities, phylogenetic ones (border shifts between regions) are significantly correlated, related to the body size, and this explains sex differences in their occurrence.

KEYWORDS: Vertebral column – Variations – Anomalies – Palaeoosteological samples – Lithuania

INTRODUCTION

Studies of vertebral variations and anomalies are of considerable interest for both medicine and anthropology due to the question of determination of criteria for "standard" and "individual variability", not elucidated is their impact on diseases of the spine and spinal cord and sometimes different frequencies in various populations.

Palaeoosteological materials serve as a valuable tool for solving the above listed questions, as they mostly represent randomised population without clinical selection and without modern iatrogenic effects.

The purpose of the study was to examine the incidence of variations and anomalies of the vertebral column, their possible correlation, influence of secular factors, sex and age and somatometric indexes on their occurrence.

MATERIALS AND METHODS

The total sample consisted of skeletons of 857 adult individuals (12,227 vertebrae, 633 sacral bones), from recent archaeological excavations in Lithuania, 50 dated to the 1st millennium AD, the remaining ones to the 2nd. Sex and age determination was performed using routine morphological criteria of the pelvis and the skull (Sjøvold 1988, Szilvássy 1988). Variations and anomalies of the spine were evaluated visually and attributed to "ontogenetic" (consequences of disturbances during complex embryogenesis of the vertebrae), "phylogenetic" (variations in number of the spine segments), and "mixed" (impaired segmentation, or vertebral blocks), according to Dyachenko (1949). Standard osteometry (Martin, Saller 1957) of the vertebrae and bones of extremities was also performed, and indices of body size – stature according to Lithuanian equations (Garmus, Jankauskas 1993), body weight according to Debetz (Debetz, Durnovo 1971) were calculated. Pelvis width was measured directly after assembling osseous pelvis.

RESULTS AND DISCUSSION

Ontogenetic variations of vertebral bodies in our sample were extremely rare – they are represented by a single case (0.19%) of *spina bifida anterior incompleta* (caused by

FIGURE 1. *Spina bifida anterior incompleta* of the 3rd thoracic vertebra (female, 25–30 years, Alytus burial ground, 15–17 cent. AD).

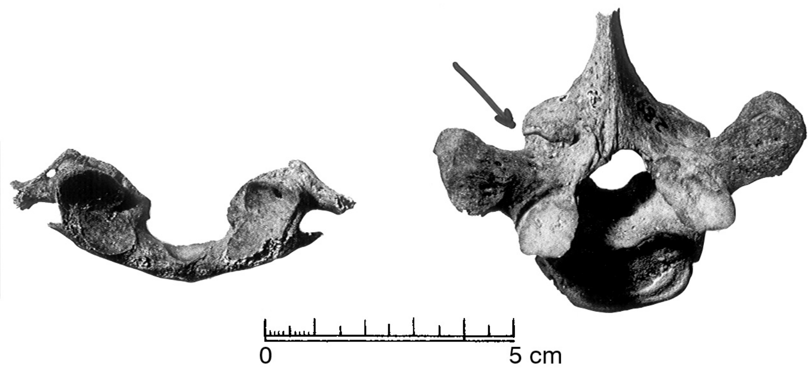

FIGURE 2. Absence of the posterior arch of the atlas (on the left) (female, 50–55 years, Alytus burial ground) and unilateral right side spondylolysis of the 2nd thoracic vertebra (on the right, arrow) (male, 45–50 years, Archicathedral of Vilnius, 16–18 cent. AD).

TABLE 1. Incidence of the *spina bifida posterior ossis sacri*, in %.

S1	S2	S3	S4	S5	S1–S5	Author
30–35	–	–	–	–	3–5	Reinberg 1964
26.7	–	–	–	76.2	–	Ferembach 1963
20	–	–	–	–	–	Kümmel, Kantz (acc. Schmorl, Junghanns 1932)
15.6	4.4	7.5	37.6	84.5	2.7	Our data
11	–	–	–	–	–	Brailsford (acc. Shvetz 1975)
10.2	–	–	–	–	–	Shvetz 1975
~10	–	–	–	–	–	Tager, Dyachenko 1971
8.8	–	–	–	–	–	Gunness-Hey 1980
8.2	–	–	–	–	–	Piontek 1971
4.69	–	–	–	–	1.56	Riegerová 1979
–	–	–	–	–	17	Berry 1975
–	–	–	–	–	2.7	Saluja *et al.* 1985
–	–	–	–	–	1.87	Rabino Massa *et al.* 1974

TABLE 2. Frequencies of lumbar spondylolysis on different vertebrae, in %.

L1	L2	L3	L4	L5	L6	Population	Author
0.5	0.5	2.2	9.1	17.1	–	Inuit	Gunness-Hey 1980
1.2	2.4	0.0	9.9	9.9	50.0	Inuit	Merbs 1983b
0.0	0.0	0.28	2.28	6.26	–	Slavic-Avaric	Vyhnánek, Stloukal 1984
–	–	–	–	1.39	–	North Amerindians	Barnes 1986
0.18	0.18	0.18	0.91	4.54	15.38	Lithuanian	Our data

the failure of resorption of the notochord in the embryogenesis – *Figure 1*). Variations of such kind are mentioned as casuistics in the literature (Farkas *et al*. 1976, Merbs 1983a).

Variations of the vertebral arches were much more commonly found, and they can be clustered into the *spina bifida posterior* (*occulta*, if clinical symptoms are absent) and spondylolysis groups. In our samples, *spina bifida* was found in all regions of the spine, most often on its cranial, and especially caudal ends. Seven cases of *spina bifida atlantis posterior* (1.45±0.54%) and two of axis (0.48±0.34%) were found. Thoracic (3 cases, 0.64±0.37%) and lumbar (2 cases, 0.38±0.27%) *spina bifida* were much less numerous. Sacral *spina bifida* was quite a common find (*Table 1*). Open sacral canal at the level of S5 was more a rule than an exception, followed by S4 and S1. Sex and age differences were insignificant. In general, our data are close to data of other authors.

Cases of spondylolysis in cervical and thoracic regions were an extremely rare find, represented by single cases (*Figure 2*). As a rule, this anomaly occurs most frequently on the 5th lumbar vertebra, in the interarticular region, and

FIGURE 3. Right side spondylolysis of the 1st sacral vertebra (arrow) (adult male, Alytus burial ground).

FIGURE 4. Block of the right hemivertebra of atlas with axis; left side of atlas is missing. Asymmetry of the vertebral column was compensated by asymmetric occipital condyles (female, 20–25 years, Alytus burial ground).

as bilateral, although cases of other localisation and unilateral spondylolysis were also noted. It was also detected on other lumbar vertebrae (*Table 2).* Moreover, high frequency of spondylolysis in cases of complete lumbalization of the 1st sacral vertebra (13 cases of lumbalization – 2 cases of spondylolysis) and one case of the right side spondylolysis of the 1st "true" sacral vertebra (*Figure 3)* should be mentioned. In general, sex and age differences of spondylolysis occurrence were insignificant. Several theories created at various times proposed explanations on the aetiology of this anomaly (hereditary causes, traumatic origin, fatigue fracture, displastic – for discussion, see Merbs 1996). Inuit populations, as well as Avar people are characterised by the high incidence of spondylolysis; some North Amerindian, as well as Saami populations are also distinct. In the world range of the spondylolysis incidence, Lithuanian materials fit into the middle of variation (*Table 3).*

"Mixed" variations were represented by the congenital vertebral blocks. Such blocks (in all cases, vertebral body height was normal, traces of intervertebral disc persistent, neither signs of anterior longitudinal ligament ossification, nor osteophytes of anterior surfaces of vertebral bodies,

TABLE 3. Lumbar spondylolysis incidence in various populations.

Percentage	Population	Author
41.3	Inuit	Lester, Shapiro 1968
33.3	Avar, 7–8 cent. AD	Éry 1974
30.2	Inuit	Gunness-Hey 1980
26.3	Inuit	Stewart 1953*
18.9	Slavic-Avar, 7–8 cent. AD	Vyhnánek, Stloukal 1984
13.2	North Amerindians	Gunness-Hey 1980
12.8	Saami	Schreiner 1935**
9.5	English, Medieval	Birkett 1984
9.1	Japanese	Hasebe 1913**
8.2	Australians	Tulsi 1972*
7.3	Japanese	Stewart 1931*
6.5	Lithuanian, Medieval	Our data
6.3	Slavic, 9–12 cent. AD	Vyhnánek, Stloukal 1984
6.1	Bantu Africans	Shore 1929–30*
5.8	North American Whites	Roche, Rowe 1951*
5.8	British, 1st mill. AD	Brothwell, Powers 1968*
5.8	Anglo-Saxons	Manchester 1982
5.2	African Blacks	Gunness-Hey 1980
5.0	North Amerindians	Cogdon 1932*
5.0	Germans	Neugebauer 1882*
4.9	East Africans	Albrook 1955*
4.0	Germans	Schwegel 1859*
1.9–5.0	North American Blacks	Gunness-Hey 1980
3.8	North Amerindians	Stewart 1931*
3.8	South Amerindians	Stewart 1931*
2.9	Central Europeans	Hayek 1929*
2.4	North American Blacks	Roche-Rowe 1951*

* – acc. Vyhnánek, Stloukal 1977; ** – acc. Gunness-Hey 1980

TABLE 4. Correlation coefficients between "phylogenetic" variations of the spine and body measurements (positive correlation – cranial shift, negative – caudal shift).

	Males			Females		
	Stature	Body weight	Pelvis width	Stature	Body weight	Pelvis width
Cervico-thoracic	0.181*	0.119	0.153	0.079	0.084	0.155
Thoraco-lumbar	0.093	0.063	0.083	0.140	–0.048	0.009
Lumbo-sacral	–0.011	–0.024	–0.086	–0.062	–0.072	–0.112
Sacro-coccygeal	–0.106	–0.027	–0.220**	–0.072	–0.260*	–0.155

* – $p < 0.05$, ** – $p < 0.01$

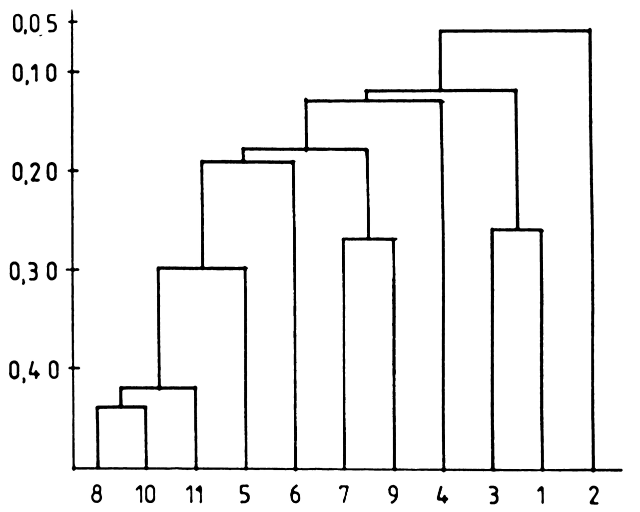

FIGURE 5. Clusterization of the Pearson's coefficients of conjugation of variations and anomalies of the vertebral column (1 – *ponticulus atlantis posterior*; 2 – *spina bifida atlantis*; 3 – *spina bifida ossis sacri*; 4 – cervico-thoracic transition; 5 – thoraco-lumbar transition; 6 – superior articular processes of Th12; 7 – inferior articular processes of Th12; 8 – lumbo-sacral transition; 9 – spondylolysis; 10 – form of the sacral bone (hypo- or hyperbasal); 11 – number of sacral segments).

sometimes also fusion of vertebral arches – Vyhnánek, Stloukal 1985) were found in all regions of the spine, but most often – in the cervical area: 12 cases, 2.57±0.73%, (*Figure 4* is a rare case of the cervical block), less frequently – in the thoracic (6 cases – 1.59±0.64%). Lumbar blocks were much less common (3 cases – 0.54±0.31%).

Phylogenetic variations, or cranial/caudal shifts of borders between vertebral regions that reflect phylogenetic trends, can be divided into "uncompensated", when the total number of vertebrae is different from normal, and "compensated", when just the morphology of the vertebra has changed and became more similar to the adjacent region, thus shifting the border between the spine regions (Khrisanfova 1962). We have not found, and literature data support our opinion (Gupta *et al.* 1977), "uncompensated" variations, but "compensated" border shifts occurred in all regions.

Cervico-thoracic variations were rare. In 3 cases of supposed cervicalization (reduction of the 1st rib), absence of *fovea costalis transversalis* on Th1 was noted (0.54±0.31%). Total number of complete thoracalization of C7 (manifestation of the cervical rib) was also 3. Presence of transversal costal facet with corresponding reduction of transversal process was taken for diagnostic criteria, as no true cervical rib was identified (most probably lost postmortally). Literature gives incidence of cervicalization less than 1%, thoracalization – 0.3–2% (Khrisanfova 1962, Tager, Dyachenko 1971).

In the thoraco-lumbar region, various forms of cranial shift (lumbalization of Th12 – absence of rib facets) were observed more frequently (24 cases, 4.94±0.98%) than caudal – thoracalization of L1 (presence of the 13th pair of ribs – 5 cases, 1.03±0.46%). Frequency of variations of this region increases considerably if the form of the articular processes of Th12 (lumbar, if forming an angle open dorsally, or thoracic, if remaining in one plane) is taken into account. "Typical" forms of those processes (upper – thoracic, lower – lumbar) were found in only 60.87±2.63%. For males, higher incidence of lumbar forms of upper processes, and females – thoracic forms of lower ones (in both cases $p < 0.05$) were noted. Due to the high variability of forms of shifts in this area, literature data differ considerably.

For the lumbo-sacral region, variations were a relatively common find, and they manifested themselves by various morphological forms. Both sacralization (cranial shift) and lumbalization (caudal shift), possible to determine only when the vertebral column is complete, can be divided into the following categories: supplementary articular surfaces on lateral processes present (one or both sides); unilateral ossification; bilateral ossification. All forms of lumbalization were more common for males than for females (8.64±1.51% and 4.42±1.30% correspondingly, $p < 0.05$). As different forms of manifestation are taken into account, literature data vary considerably and are hardly compatible.

In the sacro-coccygeal area, shifts are also possible in both directions – cranial (coccygeization) and caudal (sacralization). In our materials, sacralization of Co1 was extremely frequent (42.43±3.00% for males and 35.46±3.65% for females, although difference was statistically insignificant). Similar and even higher frequencies can be found in literature (Khrisanfova 1962, Tager, Dyachenko 1971). Thus "standard" 5 sacral segments were noted in only 59.83±2.28% of cases. Sacral bones consisting of 6 segments were quite common (35.42±2.22%); sometimes they had 7 and even more segments (3.67±0.87%), especially in males. Reverse tendency (4 segments) was found in 1.08±0.48%.

An attempt was made to find relations between the above mentioned and some other vertebral variations. Correlation analysis and clusterization of Pearson's coefficients of conjugation (*Figure 5*) revealed that ontogenetic variations are not correlated – they are independent individual characteristics (right side of the dendrogram). On the contrary, phylogenetic variations demonstrated weak, albeit significant positive interrelations (left side of the dendrogram). This points to the same direction of the shift of borders between regions, especially when minor forms of the shift are taken into account, as phylogenetic variations could hardly be described as discrete.

Moreover, certain correlation with vertebral and total body measurements was traced (*Table 4*): tendency for the cranial shift in cervico-thoracic and thoraco-lumbar, and caudal – in lumbo-sacral and sacro-coccygeal regions with increase of the size of the vertebral column and the body size. This can explain sexual differences in the incidence of phylogenetic variations.

CONCLUSIONS

Two groups of vertebral variations and anomalies can be distinguished. The first one – ontogenetic variations, independent discrete traits that are correlated neither with each ether, nor with sex, age or body build of an individual. The second one – phylogenetic variations, related to some extent with each other and manifesting some sex differences in their incidence, most probably due to their dependence on the body measurements. Besides, due to remarkable variability of the forms of their manifestation, they could be hardly considered as discrete. This should be taken into account when performing inter-population comparisons. As for spondylolysis, both biomechanical (fatigue fracture) and genetic factors, expressing themselves either directly, either through other morphological peculiarities (e.g. lumbalization of the 1st sacral vertebra) should be considered.

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