

Developmental Anomalies in Skeletal Remains from the Great Moravia and Middle Ages Cemeteries at Devín (Slovakia)

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ABSTRACT Developmental anomalies were scored and prevalences were computed for two skeletal collections from Devín (southwestern Slovakia). The first sample Devín-Hrad (DH) is dated to the Middle Ages (11th–12th century) and includes 217 skeletons. The second collection Devín-Za kostolom (FR) includes 112 burials and is dated to the Great Moravian period (9th century). In both samples, the evidence of *spina bifida occulta* occurred most frequently of all the defects examined (24% in DH, 23% in FR). Sacralization (8% in DH, 7% in FR) was more common than lumbarization (2% in DH, 0% in FR), and spondylolysis (7% in DH, 4% in FR) was relatively frequent in both samples. The other developmental defects occurred in only one or a few individuals and represented sporadic occurrences. Copyright © 2003 John Wiley & Sons, Ltd.

Key words: developmental anomalies; the Great Moravia; the Middle Ages; Devín; Slovakia

Introduction

Skeletal developmental defects are characterized as a disruption in the normal bone structure and often result from disturbed chemical function due to a metabolic deficiency (Gregg & Gregg, 1987). Developmental defects are affected by genetic influence or by an environmental stimulus at a critical time in fetal growth when developing structures are vulnerable. Developmental anomalies can appear pre- or post-natally and may vary from less serious disturbances in development to major abnormalities.

Major abnormalities can be lethal in the early stages of life and therefore the study of developmental defects in skeletal remains is mostly limited to the presence of less serious disturbances that cause minor health problems to their sufferers. Zimmerman & Kelley (1982) hypothesized that most skeletal anomalies result from fusion abnormalities, additional ossification centres, accessory structures, underdeveloped structures, agenesis or generalized skeletal anomalies. In historical populations, the majority of developmental skeletal anomalies are localized in the spine, and most frequently in the lumbosacral region.

Developmental defects have been recognized and cases reported in many prehistoric and historic skeletal collections throughout the world (e.g. Ortner & Putschar, 1981; Webb, 1995; Lynnerup, 1998; Anderson, 2000), but only a

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few studies have examined the epidemiology of developmental defects in skeletal populations (e.g. Gregg & Gregg, 1987; Barnes, 1994).

The aim of this study was to analyse the prevalence of different developmental defects in order to explain the pattern of continuity between two skeletal populations from similar time periods and locations. Interpopulation and intrapopulation variability of developmental defects prevalences was examined. The results are discussed and the populations are compared with other osteoarchaeological samples as well as with clinical data.

The study is part of a palaeopathological research project focused on documenting and analysing palaeoepidemiological data from historical populations from the Devín site.

Material and methods

Devín, with the ruins of an extensive fortification localized on a sheer rock cliff above the confluence of the Danube and Moravia rivers, represents today the northwest part of Bratislava, capital of Slovakia. The locality of Devín Gate is one of the most important archaeological sites in Slovakia. Excavated remains, of which the

oldest were dated to the Later Stone Age (5000 BC), show that the most well represented cultures were the Latene (400–100 BC), Roman (100–500 AD) and Great Moravian (9th century AD). After the fall of the Great Moravian Empire, the Devín Castle settlement became an important strategic fortification of the Hungarian monarchy. Archaeological excavations began in the second decade of the 20th century and with few interruptions continue today (Plachá *et al.*, 1990).

In this study a total of 327 individuals from two cemeteries at the Devín site were examined (Figure 1). The first skeletal collection represents the remains of 217 individuals (61 males, 68 females, 21 adults with indeterminate sex and 67 children) from the cemetery located inside the medieval fortification of Devín-Hrad site (DH), dated to the Middle Ages (11th–12th century). The second skeletal collection consists of 112 individuals (38 males and 28 females, 10 adults with indeterminate sex and 36 children) excavated from the periphery at the Devín-Za kostolom site (FR), dated to the Great Moravian Period (9th century).

Ageing and sexing were performed by one of the authors (R.B.) using standard morphological criteria (according to Buikstra & Ubelaker, 1994). Skeletal remains were macroscopically examined

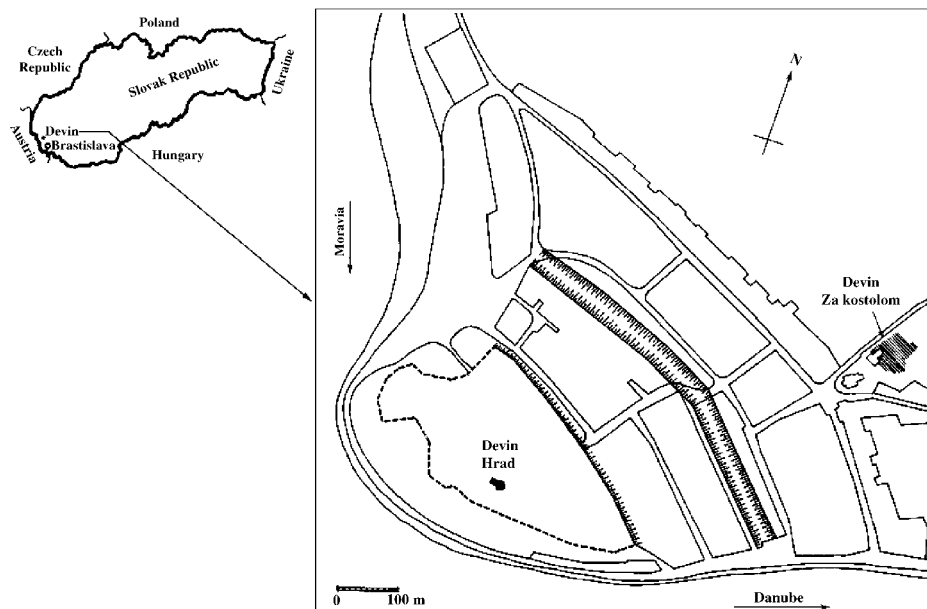


Figure 1. Map of site locations at Devín.

and the presence or absence of axial skeleton anomalies, such as *spina bifida occulta*, cranial-caudal vertebral border shifting, congenital block vertebra, hypoplasia and aplasia of bones, irregular segmentation of ribs, sternal defects (according to Barnes, 1994), and developmental defects of the appendicular skeleton (according to Ortner & Putschar, 1981), was recorded. The rates of prevalence of particular lesions were computed, and intrapopulation and interpopulation differences were analysed using Fisher's exact test.

Results

The prevalence of different types of developmental defects in the studied populations are summarized in Tables 1 and 2. Because of poor preservation of subadults and the fact that some anomalies do not become apparent until later in life, only premature cranial synostose was scored in subadults.

It is apparent that the most frequent anomalies are defects of the vertebral column—clefing of sacrum, spondylolysis and sacralization in both populations (Table 1 and 2), while cranial abnormalities and defects of the appendicular skeleton are rare.

Table 3 summarizes the results of intrapopulation and interpopulation statistical tests. Although slight sex differences were observed in some types of developmental lesions they were not statistically significant with the exception of sacralization in the DH sample. The results show that neither interpopulations differences were statistically significant.

Discussion

Cranial defects

There were only a few cases of cranial abnormalities observed in both studied samples (Tables 1

Table 1. Occurrences and prevalences of developmental defects in DH sample

	Males		Females		Non sexed adults		Total	
	Occur.	Preval. (%)	Occur.	Preval. (%)	Occur.	Preval. (%)	Occur.	Preval. (%)
Cranial defects								
Nasal bone hypoplasia	0/27	0	0/34	0	0/10	0	0/71	0
Premature suture synostoses*	0/30	0	0/35	0	0/10	0	0/98*	0
Precondylar articulating facet	1/28	4	0/30	0	0/10	0	1/68	1
Stafne's defect	1/32	3	0/41	0	0/11	0	1/84	1
Vertebral defects								
<i>Asimilatio atlantis</i>	0/26	0	1/37	3	0/11	0	1/74	1
Sacralization	7/46	15	1/53	2	1/13	8	9/112	8
Lumbarization	1/46	2	1/53	2	0/13	0	2/112	2
Developmental block vertebra	2/42	5	2/57	4	0/15	0	4/99	4
Th4 + 5	1/42	2	0/55	0	0/15	0	1/112	1
Th3 + 4	1/40	3	2/57	4	0/12	0	3/109	3
<i>Spina bifida occulta</i>	11/43	26	10/52	19	5/14	36	26/109	24
S1–2 and S4–5	2/43	5	1/52	2	0/14	0	3/109	3
S2	2/43	5	2/52	4	0/14	0	4/109	4
S2–5	1/43	2	0/52	0	1/14	7	2/109	2
S3–5	3/43	7	2/52	4	0/14	0	5/109	5
S4–5	2/43	5	3/52	6	3/14	21	8/109	7
<i>Canalis sacralis apertus (S1–5)</i>	1/43	2	2/52	4	1/14	7	4/109	4
<i>Spina bifida atlantis posterior</i>	1/26	4	0/37	0	0/11	0	1/74	1
Spondylolysis	4/53	8	5/65	8	1/18	6	10/136	7
L5	3/53	6	4/65	6	1/18	6	8/136	6
L4 + 5	1/53	2	1/65	2	0/18	0	2/136	1
Other postcranial defects								
<i>Costa lumbalis</i>	3/52	6	0/65	0	1/18	6	4/135	3
<i>Costa cervicalis</i>	0/52	0	0/65	0	0/18	0	0/135	0
<i>Perforatio sterni</i>	3/39	8	0/34	0	1/12	8	4/85	5
Congenital hip dislocation	1/45	2	0/50	0	0/12	0	1/107	1

*Total occurrence and prevalence of premature suture synostoses are computed with children's skeletons included.

Table 2. Occurrences and prevalences of developmental defects in FR sample

	Males		Females		Non sexed adults		Total	
	Occur.	Preval. (%)	Occur.	Preval. (%)	Occur.	Preval. (%)	Occur.	Preval. (%)
Cranial defects								
Nasal bone hypoplasia	0/18	0	1/17	6	0/5	0	1/40	3
Premature suture synostoses*	0/22	0	0/16	0	0/7	0	1/72*	1*
Precondylar articulating facet	0/20	0	0/17	0	0/6	0	0/43	0
Stafne's defect	2/20	10	0/17	0	0/3	0	2/40	5
Vertebral defects								
<i>Asimilatio atlantis</i>	0/4	0	0/3	0	0/1	0	0/7	0
Sacralization	1/16	6	1/13	8	0/0	0	2/29	7
Lumbarization	0/16	0	0/13	0	0/0	0	0/29	0
Developmental block vertebra	0/11	0	0/9	0	0/0	0	0/20	0
<i>Spina bifida occulta</i>	5/14	36	1/11	9	0/1	0	6/26	23
S1-2 and S4-5	2/14	14	1/11	9	0/1	0	3/26	12
S3-5	2/14	14	0/11	0	0/1	0	2/26	8
<i>Canalis sacralis apertus (S1-5)</i>	1/14	7	0/11	0	0/1	0	1/26	4
<i>Spina bifida atlantis posterior</i>	0/4	0	0/3	0	0/1	0	0/7	0
Spondylolysis	2/24	8	0/17	0	0/4	0	2/45	4
L5	2/24	8	0/17	0	0/4	0	2/45	4
Other postcranial defects								
<i>Costa lumbalis</i>	0/24	0	0/17	0	0/4	0	0/45	0
<i>Costa cervicalis</i>	0/23	0	0/17	0	0/4	0	0/44	0
<i>Perforatio sterni</i>	0/10	0	0/9	0	1/1	100	1/20	5
Congenital hip dislocation	0/15	0	0/13	0	0/2	0	0/30	0

*Total occurrence and prevalence of premature suture synostoses are computed with children's skeletons included.

Table 3. Sex and interpopulation differences evaluated by Fisher's exact test (*p* values)

	Sex		Interpopulation DH/FR
	DH	FR	
Nasal bone hypoplasia	—	—	0.3636
Premature suture synostoses	—	—	0.4235
Precondylar articulating facet	0.4828	—	1
Stafne's defect	0.4384	0.4895	0.2431
<i>Asimilatio atlantis</i>	1	—	1
Sacralization	0.0233*	1	1
Lumbarization	0.5819	—	1
Developmental block vertebra	1	—	1
<i>Spina bifida occulta</i>	0.4695	0.1804	1
<i>Canalis sacralis apertus</i>	1	1	0.9510
<i>Spina bifida atlantis posterior</i>	0.4127	—	1
Spondylolysis	1	0.5024	0.7329
<i>Costa lumbalis</i>	0.0850	—	0.5734
<i>Costa cervicalis</i>	—	—	—
<i>Perforatio sterni</i>	0.2432	—	0.9534
Congenital hip dislocation	0.4737	—	1

*Significant difference at *p* < 0.05.

and 2). One interesting case was the premature synostosis of part of the coronal suture on the left side and squamosal suture on the right side, which caused slight asymmetrical development of the skull in a juvenile individual from FR sample

(Figure 2). Nasal bone hypoplasia (Figure 3), found in a young female from the FR sample, represents a skeletal anomaly rarely reported in the palaeopathological literature. However, Snow (1974) found a tendency for developmental disturbance in the formation of nasal bones in prehistoric Hawaiians. He identified bilateral and unilateral aplasia, as well as hypoplasia of the nasal bones in several prehistoric Hawaiian skulls. A precondylar articular facet resulting from caudal shifting at the occipito-cervical border was present in one male from the DH sample. A precondylar articular facet may articulate with both the atlas and dens, or with the dens or with only the atlas (Barnes, 1994). In this case it articulated only with the dens.

Stafne's defect, first described by Stafne (1969), is a circular or oval concavity located in the lingual surface of the mandible, inferior to the mylohyoid line, usually below the third molar, or retromolar region. It may be bilateral or unilateral with the left side affected more frequently, and is predominately found in males between 40 and 50 years of age (Barnes, 1994). Stafne's defect was found in one male from the DH sample (1%) and in two males from the FR sample (5%). In all

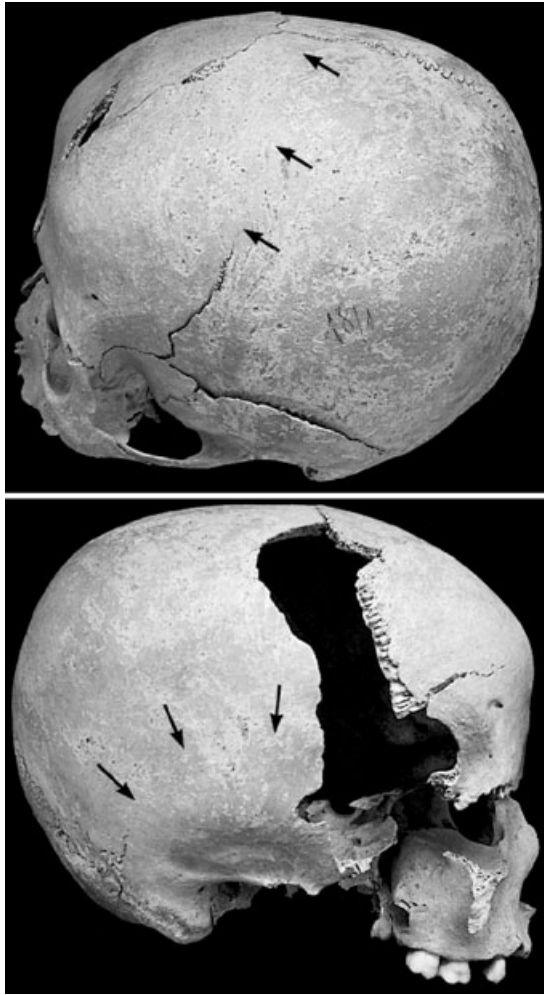


Figure 2. Premature synostosis of part of the coronal suture on the left side (arrows; top image) and squamosal suture on the right side (arrows; bottom image) in the skull of a juvenile individual FR18/1.



Figure 3. Nasal bone hypoplasia (arrow) in a young female FR36.

three cases the defect was observed on the right side, in male individuals of the age category *maturus* 1 (40–50 years). Slight interpopulation difference, which is non-significant, may reflect the effect of sample size bias. The mean prevalence from both samples (3%) is in close agreement with the 3% (10/295) prevalence found in the Avar period sample from Hungary (Finnegan & Marcsik, 1981), and the values reported by Mann & Shields (1992) for Caucasian samples.

Vertebral defects

Vertebral column anomalies, such as developmental delays of vertebral elements (clefing of the sacrum), segmental border shifting, and spondylolysis were the most common developmental defects in both samples (Tables 1 and 2).

Asimilatio atlantis was present in one female from the DH sample (1%). *Asimilatio atlantis* (atlas occipitalization) results from the complete or partial congenital fusion of the arch of the atlas with the occipital bone. Abnormal caudal shifting of the occipito-cervical border that leads to occipitalization of the atlas is more common than cranial shifting which manifests as an occipital vertebra (Barnes, 1994).

The lumbosacral region is the most frequent site of border shifting. Abnormal cranial shifting leads to sacralization of the fifth lumbar vertebra (L5), while caudal shifting leads to lumbarization of the first sacral vertebra (S1). In both cases, the defect may be complete or incomplete, unilateral or bilateral, symmetrical or asymmetrical (Barnes, 1994). Expressions of cranial shifting (sacralization) were more common (8% in the DH sample, 7% in the FR sample) than expressions of caudal shifting (Tables 1 and 2). Lumbarization occurred only in two individuals (2%) from the DH sample. According to Stloukal & Vyhnánek (1976) transitional vertebra at lumbosacral border are more frequently observed in males. This tendency was confirmed in the DH sample where sacralization occurred significantly more frequently in males ($p < 0.05$) (Table 3).

A developmental defect resulting in aplasia or hypoplasia of one or both parts of the neural arch and/or spinous process, is usually referred to as

spina bifida occulta or cleft neural arch. This defect is the most common developmental defect of the vertebral column in historical skeletal series (Stloukal & Vyhnánek, 1976; Gregg & Gregg, 1987; Barnes, 1994). This condition is quite frequent particularly in the lumbosacral border (L5 and S1), with reported incidences up to 25% (Barnes, 1994). Usually, only one or two vertebrae are affected, but occasionally more can be, particularly in the sacral neural arches. Males appear to be more frequently affected by developmental delay defects in the sacrum than females (Barnes, 1994; Aufderheide & Rodríguez-Martín, 1998; Mann & Murphy, 1990). This condition has to be differentiated from the more serious problem of *spina bifida cystica*, which is the neural tube defect. Genetic studies show that *occulta* and cystic forms of *spina bifida* are different expressions of the same dominant gene (McKusick, 1998).

Spina bifida occulta was more frequently recorded in the DH sample. It was recognized in 26 individuals (24%) from the DH sample, non-significantly more often in males (26%:19%). In the FR sample a similar prevalence was observed as in the DH sample (23%), and again with a non-significantly higher prevalence in males (36%:9%). The majority of these defects involved lower sacral segments (S4–5, S3–5) followed by simultaneous involvement of the first, second, fourth and fifth sacral segments (S1–2 and S4–5) (Tables 1 and 2).

The prevalences obtained are similar to those reported in a recent Czech population (20%) (Bláha, 1963), and in a recent Slovak population (18%) (Vojtaššák, 1998). In a study of a Slavic population from Mikulčice *spina bifida occulta* occurred less frequently (8%) (Stloukal & Vyhnánek, 1976).

When clefting occurs in all sacral segments, and creates a complete cleft sacrum, it is called *canalis sacralis apertus*. There were four cases of this lesion found in the DH sample, two of them in females, one in a male and one in an individual of intermediate sex (Table 1). Only one male was found in the FR sample with *canalis sacralis apertus* (Table 2). Our prevalences are similar to those obtained by Jankauskas (1994) in Lithuanian populations from the first and second millennium AD (3%).

Spina bifida atlantis posterior or clefting of the posterior arch of the atlas was found only in one male (1%) from the DH sample (Table 1). Similarly, in a historic Lithuanian population 1–2% of cases were reported (Jankauskas, 1994). Vyhnánek (1986) examined atlases in skeletal remains derived from 14 Slavonic and Great Moravian populations and found developmental defects of the atlas with a prevalence of 1.2% (21/1672), of which 0.8% (14/1672) had *spina bifida atlantis posterior*. He did not find significant sex differences.

Failure of segmentation in the vertebral column results in the occurrence of developmental block vertebrae. There is usually complete unity between the centra with complete or incomplete fusion of the neural arches (Barnes, 1994). According to Vyhnánek *et al.* (1965) block vertebrae are one of the most common congenital anomalies recorded in historic populations. In our skeletal samples, four individuals from the DH sample had this condition (Table 1). In one male individual the presence of block vertebrae occurred in the fourth-fifth thoracic vertebrae (Th4–5) (1%), and in other three individuals block vertebrae occurred in Th3–4 (3%) (Figure 4). Jankauskas (1994) reported that the lesion occurred in prevalences of 2.6% for cervical, 1.6% for thoracic and 0.5% for lumbar regions in Lithuanian skeletal collections.

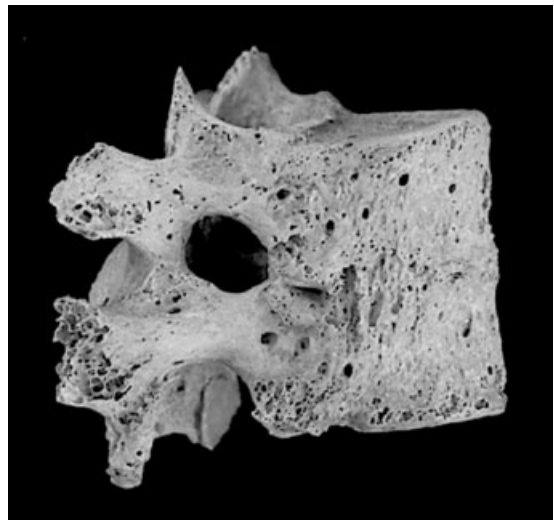


Figure 4. Developmental block vertebrae (TH3 + 4) in a female individual DH14/80.

Spondylolysis is the ossification union failure or fracture of the pars interarticularis of the vertebra, resulting in separation of the vertebra into two parts, which occurs more commonly in S1 and L3–L5; males are more frequently affected (Barnes, 1994; Stloukal & Vyhnánek, 1972). The aetiology of this condition is controversial. Some reports view spondylolysis as a congenital malformation due to developmental ossification failure of the laminae (e.g. Snow, 1974; Shahriaree *et al.*, 1979), and others as the result of mechanical stress in the lumbosacral region (e.g. Merbs, 1995, 2002; Bridges, 1989). Haukipuro *et al.* (1978) studied spondylolysis in a Finnish kindred descendant from two marriages of a man born in 1868 and data obtained support the concept of autosomal dominant inheritance with variable expressivity of a 'spondylolysis gene'. According to Porter & Park (1982) both causes (congenital and traumatic) may play a role so there may be a possibility of congenital predisposition to a stress fracture of the pars interarticularis. Larsen (1997: 191) wrote: 'there may well be genetically based predisposing factors for spondylolysis, but the mechanical environment prompting its appearance is required'.

Relatively high frequencies were reported in populations involved in mechanically demanding activities, for example in Canadian Inuits 13% (Merbs, 1983), and in Archaic Indians 18.5% (Bridges, 1989). Sport activities can increase the frequencies. This can be seen in Japanese athletes where 20.7% are affected by spondylolysis (Hoshina, 1980). In a modern population from Slovakia 6% of population has the lesion, 80% on L5 and 15% on L4 (Vojtaššák, 1998).

The prevalence of spondylolysis was non-significantly higher in the DH sample (7%) with the L5 most commonly affected (Table 1). No significant sex differences were recorded. In the FR sample spondylolysis was found only in two males (4%), and in both cases L5 was affected (Table 2). The frequencies of spondylolysis among Slavic populations from the nearby territories vary in a range of 2–7% in Mikulčice, Bílina, Libice, Znojmo, and Abrahám (Stloukal & Vyhnánek, 1976). Similar to our results is prevalence of spondylolysis reported for a historic Lithuanian population (6.6%) (Jankauskas, 1994).

Other postcranial defects

Perforatio sterni (sternal aperture) is a developmental defect caused by incomplete fusion of the lower two or three sternal segments as they ossify separately from left and right centres. Clinical studies show that sternal apertures are twice as common in males as in females (McCormick, 1981). *Perforatio sterni* was present in four individuals, three males and one indeterminate individual in the DH sample (Table 1). In the FR sample, only one indeterminate individual was found to have this condition (Table 2).

Supernumerary ribs are the result of shifting in border regions (Barnes, 1994). Cranial shifting of the cervicothoracic border causes the development of cervical ribs. Caudal shifting of the thoracolumbar border may produce lumbar ribs. Lumbar ribs were present in four individuals, three males and one indeterminate individual from the DH sample (Table 1). No evidence of supernumerary ribs was found in the FR sample (Table 2).

Congenital dislocation of the hip is the loss of the normal relationship between the femoral head and the acetabulum. Specifically, the femoral head is not appropriately positioned in the acetabulum and undergoes complete or partial displacement out of the acetabulum. As a result of this displacement, the acetabulum becomes dysplastic, the head deforms and flattens, and a neoacetabulum (false acetabulum) is formed on the innominate bone (Aufderheide & Rodríguez-Martín, 1998).

The lesion is one of the most common skeletal congenital anomalies in modern societies (Vojtaššák, 1998; McKusick, 1998), however there is a great discrepancy in its frequency according to geographic and ethnic differences. For Caucasian population, an incidence of 1 per 1000 live births can be assumed. It occurs five times more frequently in females. Congenital dislocation of the hip occurs as an isolated anomaly, or it can be associated with more general disorders represented by several syndromes and with chromosomal abnormalities, such as trisomy 18 (McKusick, 1998). In Slovakia 1.4% newborns are affected, and boys tend to be more affected, with a 8:1 ratio (Vojtaššák, 1998).

One male from the DH sample was found to have left-sided congenital hip dislocation



Figure 5. Congenital hip dislocation in a male DH151/85; note the small, triangular acetabulum, neo-acetabulum (arrows; left image) and flattened head of the left femur (right image).

(Figure 5). The head of the left femur was flattened, the acetabulum was small, flat and triangular and a neo-acetabulum was placed supero-posteriorly of the true acetabulum on ilium. Sacralization of L5 was also present in this individual. The frequency of congenital hip dislocation obtained for the DH sample (almost 1%) is very similar to the frequency reported for the modern Slovak population (1.4%).

Conclusion

In both studied samples, the majority of developmental defects consisted of vertebral column anomalies. The most common developmental defects were developmental delays of the vertebral elements (clefting of the sacrum), segmental border shifting, and spondylolysis. Slight sex differences in some defects were observed, however not at the level of statistical significance. According to other reports, developmental defects, such as Stafne's defect, *spina bifida occulta*, and *perforatio sterni*

tend to be seen more frequently in males. This tendency was also observed in the skeletal collections studied here. However, the prevalence of spondylolysis in the DH sample was non-significantly higher in females, while in the FR sample the usual tendency of this condition to be seen only in males was observed. Despite differences in sample size and bone preservation in both skeletal samples, a similar pattern is seen when comparing the prevalences of developmental defects, especially in the lumbosacral region (clefting, sacralization, spondylolysis).

The effects of both sample size bias and migration may be taken into account to explain slight differences in developmental defects prevalences. The Devín site was located at the crossroads of two important European long-distance trade routes, the Danube and the Amber, and therefore may have experienced a high rate of migration. However, the similarity in the prevalence patterns suggests a genetic continuity between Great Moravian and Early Medieval populations at Devín.

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