ANTHROPOLOGIE • XLVII/3 • pp. 253–263 • 2009

MARTA KRENZ-NIEDBAŁA

SKELETAL HEALTH AND GROWTH INDICATORS IN MEDIEVAL CHILDREN FROM OSTRÓW LEDNICKI, WESTERN-CENTRAL POLAND

ABSTRACT: In skeletal biology it is assumed that living conditions are reflected in the frequency and distribution of non-specific stress indicators. Since children belong to the most vulnerable section of the population, child health and growth are treated as markers reflecting well-being of the whole society. Therefore, this study combines these two areas of research: health indicators and the growth of long bones, in order to reveal the quality of life in a sample of medieval preadults. A total of 194 skeletons aged 0–15 were examined from Ostrów Lednicki cemetery, western-central Poland, dated to 13th–15th AD. For comparison purposes, data on three other Polish sites were used: medieval Cedynia dated to10th–14th and Gruczno 12th–14th as well as late-medieval/early historical site Słaboszewo dating to 14th–17th. In the Middle Ages the examined site of Ostrów Lednicki played a high political and social role, as it was one of a few residences of the then Polish kings. Cedynia was also a quite privileged site, since it lied at an important trade route leading from the north to the south of Poland. Gruczno was a well-prospering stronghold and Słaboszewo represented a local rural society typical of late medieval Polish villages.

Skeletal growth profiles of lower limb bones were constructed – mean diaphyseal lengths were plotted against yearly dental age estimates. The profiles of growth rate were also produced. For the evaluation of health status various skeletal markers were used: non-specific stress indicators – cribra orbitalia*, Harris lines, dental enamel hypoplasia and porotic hyperostosis, indicators of non-specific infection –* periostitis *and endocranial new bone formation and also traces of diet-dependent diseases, scurvy and rickets. The prevalence of* cribra orbitalia*, porotic hyperostosis and endocranial new bone formation proved markedly lower in the examined population than in the compared European samples, but the incidences of enamel hypoplasia and Harris lines were quite high. The most frequently affected individuals were from 6 to 15 years of age. The general pattern of femur growth was almost identical for all compared Polish samples, particularly in the period from 4 to 8 years of age. After the age of 8 the growth of femur in the examined population started to proceed at a higher level. The health and growth status of Ostrów preadults proved most similar to the Cedynia ones, while the preadults from Słaboszewo likely lived in the poorest conditions.*

On the basis of health indicators and skeletal growth profiles, Ostrów Lednicki preadults seem to be quite well adapted to their environment. In the Middle Ages Cedynia and, particularly, Ostrów Lednicki sites, because of their location, role in the Polish state and the social position of the inhabitants, provided more beneficial conditions for the development of children. The socio-economic status of Gruczno was definitely lower, and the lowest was of Słaboszewo, rural site, where people lived in rather unchanging poor environmental and cultural environment.

KEY WORDS: Stress indicators– Medieval subadults – Skeletal growth profiles – Health status

INTRODUCTION

The importance of child studies for the assessment of overall adaptation of a human population to its environment has become gradually appreciated since 70.ties and they are now recognized as a separate unit in an anthropological research (Lewis 2007). This is not surprising since the World Health Organization frequently states that children under five are among the most vulnerable members of a society. Child health and development parameters are treated as markers reflecting well-being of the whole society (Eveleth, Tanner 1990), for example growth as an important public health indicator for monitoring nutritional status and health as well as the prevalence of malnutrition among young children as an indicator of community nutritional stress (Davis 1996). Particularly significant for the growth process is the period from birth to 3 years of age, and especially up to the first year, since it is marked by a high growth rate (Bogin 1993). This means that nutritional requirements are huge then and the child is particularly vulnerable to adverse environmental factors, as malnutrition or diseases. Later on, the growth velocity decreases, but accelerates again at about 7–8 years and then at adolescence (Bogin 1993). During all "critical periods" of rapid growth, the child responses stronger to environmental stimuli (Ulijaszek 1998). These biological phenomena should attract special attention to examining immature remains (Saunders, Barrans 1999). However, on account of, among other things, usually low number of preadult skeletons uncovered and differential state of preservation, the number of studies on children from prehistoric and early historical times is limited. Therefore there is still a need for comparative data, gathered on all accessible health and growth indicators. It is a truism that the more information we have the more complete view of past populations we may obtain. Nevertheless, it is worthy of mention that combining two areas of research, stress markers and long bone growth, may successfully reveal morbidity and mortality pattern of a population (Ribot, Roberts 1996), especially when completed by demographic, archeological and historical data. The use of multiple indicators may also help to at least partly avoid the "non-survivor" problem in skeletal studies, since, for example, long bone lengths are general and cumulative measures of nutritional status, but are non-specific in terms of chronology, quite opposite to enamel hypoplasia which reflects developmental disturbances from a definite time period (Goodman 1993).

The current study made use of access to quite numerous osteological sample of preadults aged 0–15 years coming from medieval times and a possibility to compare the results with other Polish medieval populations that differ in their socio-economic backgrounds. It is assumed that living conditions are reflected in the frequency and distribution of non-specific stress indicators and the level of growth, so these data may provide information on how the people coped with their environmental circumstances. This paper is aimed at an evaluation of growth and health status of preadult individuals from a sample dated to 13th–15th centuries AD from Ostrów Lednicki cemetery, Poland.

MATERIAL AND METHODS

A total of 194 preadult skeletons aged 0–15 from an Ostrów Lednicki cemetery, dated to 13th–15th AD were examined. The site is located in western-central Poland and for comparison, data on three other medieval Polish sites, situated relatively nearby, were used: Cedynia dated to10th-14th AD and Gruczno 12th–14th as well as a late-medieval/early historical site Słaboszewo dating to 14th–17th AD (*Figure 1*).

FIGURE 1. Map of Poland with marked location of Ostrów Lednicki and comparative Polish medieval samples.

Ostrów Lednicki is the largest of five islands of the Lednica lake. The earliest settlement dates to the 7th/8th centuries AD. Later on, in the 10th century, a stronghold was built on the island. The 10th–11th centuries were the period of the greatest magnificence of the stronghold. In that time it served as one of a few residences of Polish kings and consisted of int. al. *palatium* and a sacramental-burial complex. Doubtless, the elite of then Polish state, must have frequently visited this site. In the 11th century the architecture of the stronghold was considerably destroyed by an invasion of the Czech prince Brzetysław. However, in the next phase, till the end of the 13th century, the entire layout with its infrastructure was rebuilt (Górecki *et al.* 1994). Invasion of the Teutonic Order in the 14th century put an end to the settlement in Ostrów Lednicki, afterwards the island served only as a burial ground (Górecki, Wrzesiński 1991). The total number of skeletons discovered there exceeds 3 thousands, in different state of preservation. In medieval Ostrów Lednicki advantageous climatic conditions and fertile soils favored the development of agriculture (Drzymała, Mocek 1994, Milecka 1994, Tobolski 1999). The subsistence was based on farming and breeding and also fishing and hunting (Wrzesińska, Wrzesiński 2005). Archeozoological data (Makowiecki 2001) evidence breeding of pigs, cattle, sheep, goats, gooses, hens and ducks. Therefore the diet was differentiated, likely providing all the necessary nutrients. Houses were constructed above-ground and underground, made of wood, clay and stone. Buildings were located close to one another and the living area was small – from 6 m^2 to 37 m^2, which made it difficult to maintain proper sanitary conditions (Górecki *et al.* 1994). They also served as handicraft workshops and in winter as a shelter for the breeding stock. Archeological data provide evidence for low sanitary conditions, that could have caused numerous diseases and even epidemics. Nevertheless, high political and social significance of Ostrów Lednicki in the Middle Ages should be emphasized. Cedynia in the medieval times lied at an important trade route leading from the north to the south of Poland by the Oder river, favoring fast development of the site (Filipowiak 1966). Since the 10th century it became a border-fortress and then gained high military and strategic importance (Malinowska-Łazarczyk 1982). The subsistence was similar to Ostrów Lednicki – based on farming and breeding, strongly supported by fishing. Gruczno in early medieval times was a well-prospering stronghold, that lied at a river route joining the south of Poland with the Baltic Sea (Kozłowski 1993). Archeological data on the grave equipment suggest relative well-being of the Gruczno population (Boguwolski, Hyss 2005). Quite different in comparison to above mentioned sites is Słaboszewo, a village, that belonged to the Gniezno archdiocese since the 15th century (Piontek 1977). The farmers of Słaboszewo represented a typical late-medieval local society (Piontek 1981), that lived far from important trade routes.

Age at death assessments were made macroscopically by dental development for deciduous and permanent dentition (Buikstra, Ubelaker 1994), as it was done for the comparative Polish samples. In the absence of teeth, skeletal maturation was assessed (Ferembach *et al.* 1980, Scheuer, Black 2000, 2004) or bone shafts measured (Stloukal, Hanákova 1978). Skeletal growth profiles based on femur and tibia lengths were constructed. Lower limb bones were chosen on account of their high growth rate and, in consequence, sensitivity to environmental stress (Eveleth, Tanner 1999). Left (when absent – right) long bone diaphyses were measured, using an osteometric board and the measurements recorded to the nearest millimeter. Mean diaphyseal lengths were plotted against yearly age estimates. In this part of the study data on individuals aged by bone measurements were not used. Then, in order to present the dynamics of femur growth, an index of growth rate was calculated, according to the following formula (Wolański 1975):

$$IGR = \frac{2\,(X_p - X_{p-1})}{t\,(X_p + X_{p-1})} \times 100$$

where IGR = index of growth rate; X_p – measurement in particular age class; X_{p-1} – measurement in the class preceding the p-class; t – time unit between both age classes.

The dynamics of femur growth was presented for the age category 2–7 years to show more clearly the expected decrease of growth rate in early childhood.

For the evaluation of health status various skeletal markers were used, in order to obtain differential and extensive information. Non-specific stress indicators: *cribra orbitalia*, Harris lines, dental enamel hypoplasia and porotic hyperostosis were examined in addition to indicators of non-specific infection: *periostitis* and endocranial new bone formation. Moreover, traces of two diseases resulting from nutritional deficiencies, scurvy and rickets, were recorded. For stress markers widely accepted recording systems were used. *Cribra orbitalia* was graded on well preserved orbital surface of frontal bones according to several classifications, described by the following authors: Stuart-Macadam (1991), Steckel *et al.* (2006), Hengen (1971), Steinbock (1976) and Mensforth *et al.* (1978) active/healed scheme. Since all these grade systems appear in the literature, such approach was applied also by other authors (Piontek *et al.* 2001). To record the condition in an individual, the roof of at least one eye socket had to be present. Dental enamel hypoplasias were scored on the enamel surface of all accessible deciduous and permanent teeth (incisors, canines, premolars and molars) as furrows or pits and the linear hypoplasias were measured from the most occlusal margin to the cemento-enamel junction (Goodman, Rose 1990). Porotic hyperostosis was recorded using Steckel *et al.* (2006) scheme, that requires at least one observable parietal to score the lesion. Steckel *et al.* (2006) classification was used also for recording *periostitis* on all accessible limb bones – at least one tibia and femur had to be preserved to make observations. Endocranial new bone formation was recorded on the inner surface of well preserved cranial vaults only by presence or absence, following Lewis (2002, 2004) description. Scurvy was diagnosed according to Ortner *et al.* (1997, 1999, 2001) indications in individuals with at least several diagnostic cranial fragments (greater wing of the sphenoid, zygomatic bone, maxilla) and long bone shafts present. Rickets was determined by splaying and cupping of the long bone metaphyses and bowing of limb bones as well as expansion of the sternal ends of the ribs (Steckel *et al.* 2006), therefore long bones and ribs were required to record the condition. Data on Harris lines had been already published and were cited from the literature (Łubocka 2003). The prevalence of the lines was estimated by the author on the basis of x-rays of femora of 167 individuals, taken with the exposure time, depending on the size of the bones, of c. 1.0 mAs 40-45 kV. The frequencies of all osteological and dental indicators were calculated as the percentage of affected individuals.

RESULTS

Age at death distribution in the examined sample of Ostrów Lednicki preadults against other European samples is presented in *Table 1*. A specific composition of the Næstved sample, which derives from a cemetery connected to a leprosarium, should be emphasized (Bennike *et al.* 2005).

TABLE 1. Age at death distribution in the sample of Ostrów Lednicki and other European preadult populations. Different age categories for Gruczno given after authors.

Age categories	Ostrów		Cedynia		Gruczno		Słaboszewo		Raunds		St. Helen		Wharram		Æbelholt		Næstved	
	number	%	number	%	number	%	number	%	number	%	number	%	number	%	number	%	number	%
0–0.5	8	4.1	11	5.5	0–0.5: 61	13.7	3	2.7	23	19.3	10	5.2	46	17.0	43	28.3	14	26.4
0.6–2.5	33	17.0	35	17.4	0.5–2: 91	20.5	20	18.0	38	32.0	45	23.3	70	25.8				
2.6–6.5	64	33.0	56	27.9	2–6: 194	43.7	26	23.4	25	21.0	64	33.2	85	31.4	57	37.5	11	20.8
6.6–10.5	47	24.2	58	28.8	6–9: 41	9.2	24	21.6	18	15.1	49	25.4	46	17.0	35	23.0	17	32.0
10.6–14.5	42	21.7	18	9.0	9–15: 57	12.9	25	22.6	11	9.2	18	9.3	13	4.8	17	11.2	11	20.8
14.6–17.0			23	11.4			13	11.7	4	3.4	7	3.6	11	4.0				
Total (0–17)	194	100	201	100	444	100	111	100	119	100	193	100	271	100	152	100	53	100

Data sources: Gruczno – Florkowski, Kozłowski (1994); Raunds, St. Helen, Wharram Percy – Lewis (2002); Æbelholt , Næstved – Bennike *et al.* (2005)

Despite slight differences in particular age categories, the general demographic pattern of the Ostrów sample does not deviate from other Middle Ages distributions. The most deaths occurred in the age category of 2.6–6.5 years. There is a relatively low number of individuals aged 0–0.5 years.

Pictures of health indicators observed in the examined sample are presented in *Figure 2*. Their frequencies and data on so far examined markers in comparative Polish populations are presented in *Table 2*. The prevalence of *cribra orbitalia* is the lowest in the studied sample, but still almost half of the preadults show the porosity of orbital roof. Enamel hypoplasia, observed in half of the examined skeletons, is more prevalent than in Cedynia and Słaboszewo groups. In those populations the frequency of scurvy and rickets is very low, slightly less than in Ostrów Lednicki. Harris lines are most frequent in Cedynia preadults, followed by Ostrów ones. Individuals of the examined sample against other European preadults are shown in *Table 3*. For Central and Southern Europe all accessible data are presented and for Northern Europe only those sites were chosen for which most indicators were recorded. The preadults of Ostrów seem to be quite well adapted to their living conditions. The prevalences of *cribra orbitalia*, porotic hyperostosis and endocranial new bone formation are markedly lower than in the populations from Great Britain, Denmark and Croatia. *Periostitis* is of average frequency. However, the incidence of enamel hypoplasia is quite high and Harris lines are most frequent in the studied sample.

The percentage of affected individuals in each age category is presented in *Figure 3* and the distribution of all cases into particular age classes is shown in *Figure 4*. It seems that the most markers are more frequent in older groups of preadults, as is the case with enamel hypoplasia, *cribra orbitalia*, porotic hyperostosis, *periostitis*, and endocranial new bone. Active forms of *cribra orbitalia* occur both in younger (1.5–6.5y) and older (10.6–15y) individuals. The most cases of healed *cribra* are encountered in the age category 2.6–10.5y. Anyway, the preferentially stressed individuals are from 6 to 15 years of age.

In *Figure 5* the fitted curve of femur growth profile is shown. The vertical line separates two ways of age assessment – dental method from bone fusion estimates. The general pattern is almost identical for all compared samples, particularly in the period from 4 to 8 years of age. After the age of 8 the growth of femur in the examined sample seems to proceed at a higher level than in other samples. The divergence in the growth process in all compared preadults is particularly apparent after the age of 12, but a different method of aging must be taken into account. Nevertheless, the sample of Cedynia is most similar to the Ostrów one and Słaboszewo preadults were likely the shortest in comparison to their peers. *Figure 6* presents the growth rate of femur in the Ostrów Lednicki sample. The dynamics of femoral growth is remarkably similar in the populations of Ostrów and Cedynia. A gradual decrease is marked starting from the age of 2 years until about five years of age, then a growth acceleration occurs. The curves for Gruczno and

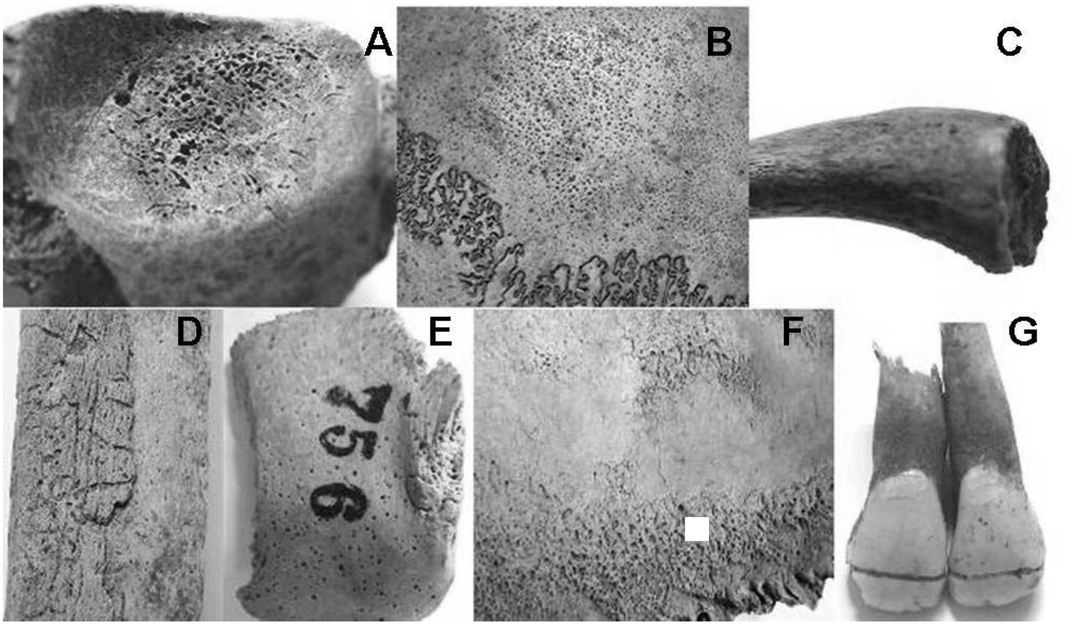


FIGURE 2. Photos of skeletal health indicators in the examined preadults from Ostrów Lednicki.
A – active cribra orbitalia, left orbit; B – porotic hyperostosis,parietal; C – rickets, sternal end of the rib; D – periostitis, tibial shaft; E – scurvy, greater wing of sphenoid; F – endocranial new bone, parietal; G – linear enamel hypoplasia, permanent incisors.

TABLE 2. Frequency of health indicators in Ostrów Lednicki preadults and other Polish medieval samples.

	Ostrów Lednicki 13th-15th	**Cedynia 10th-14th**	**Gruczno 12th-14th**	**Słaboszewo 14th-17th**
Cribra orbitalia	44.8	63.3[1]	47.8[2]	
Porotic hyperostosis	6.8			
Enamel hypoplasia	50.0	19.7		27.3
Harris lines	77.3	85.7[3]	60.9[4]	
Periostitis	25.7			
Endocranial new bone	7.3			
Scurvy	3.0	1.6		1.7
Rickets	3.1	1.1		1.3

Data sources: 1 – Jerszyńska 1991, 2 – Piontek, Kozłowski 2002, 3 – Piontek, Jerszyńska, Nowak 2001, 4 – Piontek, Jerszyńska 1993; all other data are unpublished, gathered by Krenz-Niedbała.

Słaboszewo are different – deceleration is less marked. In the Słaboszewo group there is a slow, gradual decrease of growth rate with no signs of recovery. In the Gruczno sample the decline starts later, between 3 and 4 years of age, but the growth of femur also does not accelerate.

DISCUSSION

In the skeletal studies of past populations it is assumed that the frequencies of non-specific stress indicators reflect the health status of examined samples and, in consequence, quality of living conditions. However, limitations of skeletal data to show real-life phenomena, presented by Wood *et al.* (1992) and continued by other authors (Humphrey, King 2000) should not be forgotten. At least, the examined population, basing on archeological data, seems to be homogeneous, with no strong differentiation in access to basic resources. Moreover, in this study multiple indicators were applied, associated by data on the cultural context of the once-living society, and such approach helps to reliably interpret the obtained results (Goodman 1993). In case of *cribra orbitalia* data on active and healed lesions were recorded, which is an approach appreciated long ago (Grauer 1993), in order to consider the idea that "better health makes for worse skeletons".

The comparison of frequencies of skeletal health indicators lacks many data on the samples from Cedynia, Gruczno and Słaboszewo (study in progress), therefore it is hardly possible to draw far-reaching conclusions on the differentiation of living conditions in the considered populations. In the case of *cribra orbitalia*, the frequency is

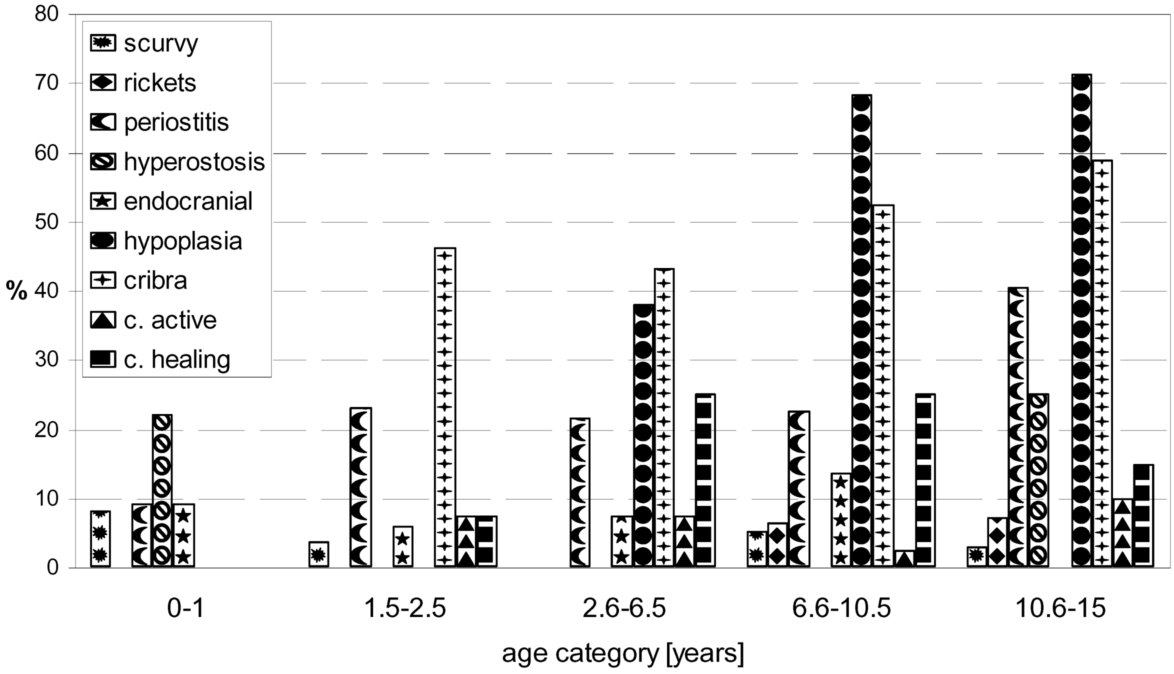


FIGURE 3. Frequency of affected individuals by age categories.

TABLE 3. Selected health indicators in medieval European samples.

Site	*Cribra orbitalia*	Porotic hyperostosis	Enamel hypoplasia	Harris lines	*Periostitis*	Rickets	Endocranial new bone
Central and Southern Europe							
Ostrów L., Poland	44.8	6.8	50.0	77.3	25.7	3.1	7.3
Mikulčice, Czech Rep.	44.0		71.2	72.9			
Borovce, Slovakia	76.9		24.0				
Stara Torina, Serbia	46.1	2.9					
Nova Rača, Croatia	58.6		64.4		55.2		31.0
Northern Europe							
Chichester, UK	67.0	15.0	38.0	42.0	55.0		
Wharram, UK	56.0		30.0		13.0	1.2	15.2
Raunds, UK	55.0	17.0	32.0	32.0	18.0		13.7
St. Helen, UK	56.0		34.0		20.0		12.0
Næstved, Denmark	57.8		42.1		25.0		6.2
Æbelholt, Denmark	52.4		16.4		8.5		8.6

Data sources: Mikulčice – Havelková *et al.* (2008), Trefný, Velemínský (2008), Velemínský *et al.* (2009); Borovce – Obertová, Thurzo (2004), Obertová (2005); Stara Torina – Djuric *et al.* (2008); Nova Rača – Šlaus (2000); Chichester – Ribot, Roberts (1996); Wharram Percy, Raunds Furnells, Saint Helen – Lewis (2002); Æbelholt , Næstved – Bennike *et al.* (2005)

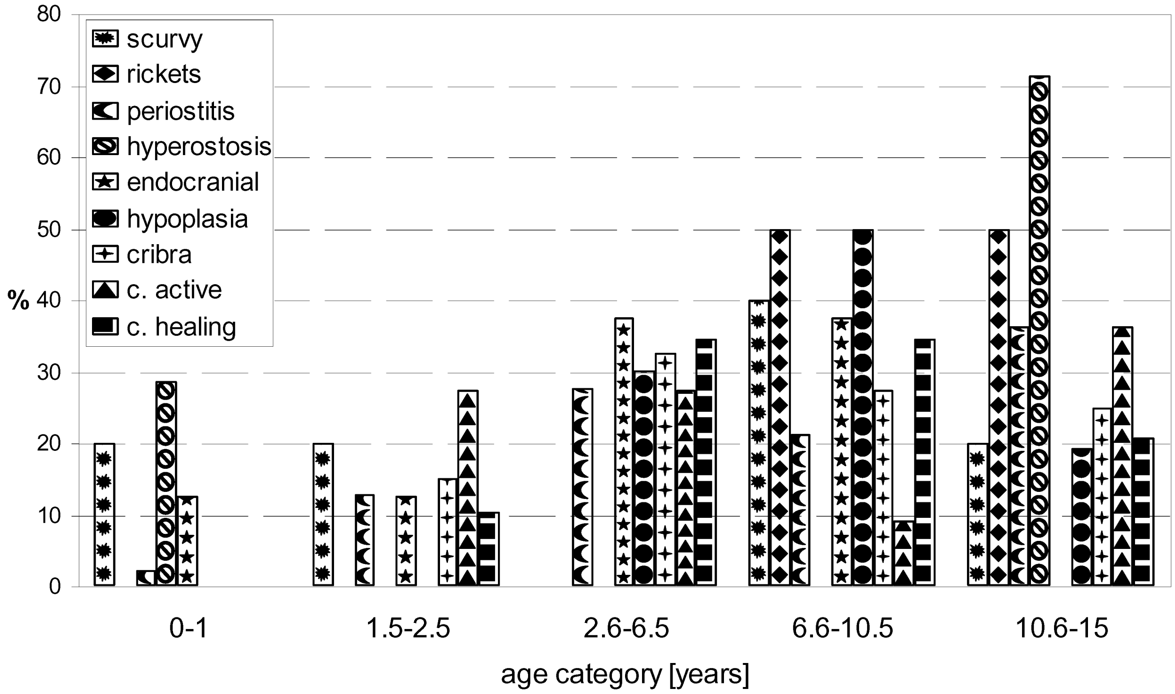
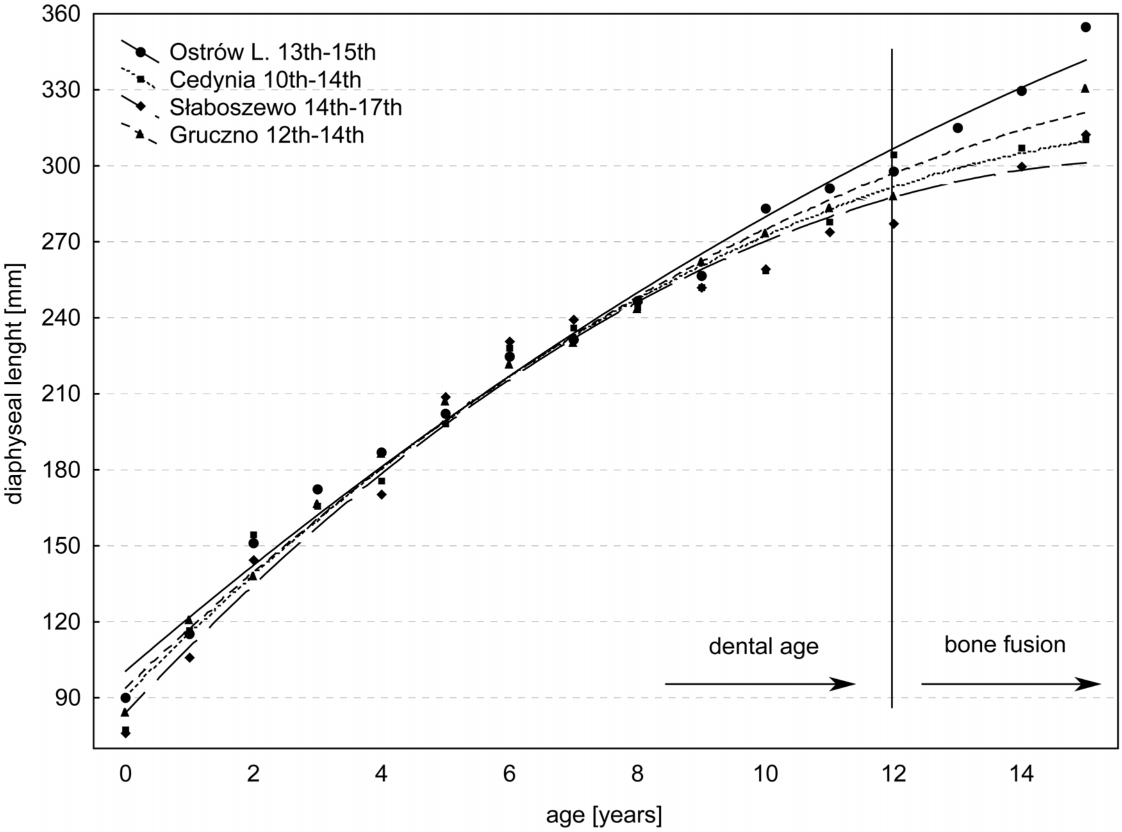


FIGURE 4. Percentage distribution of all cases into age categories.

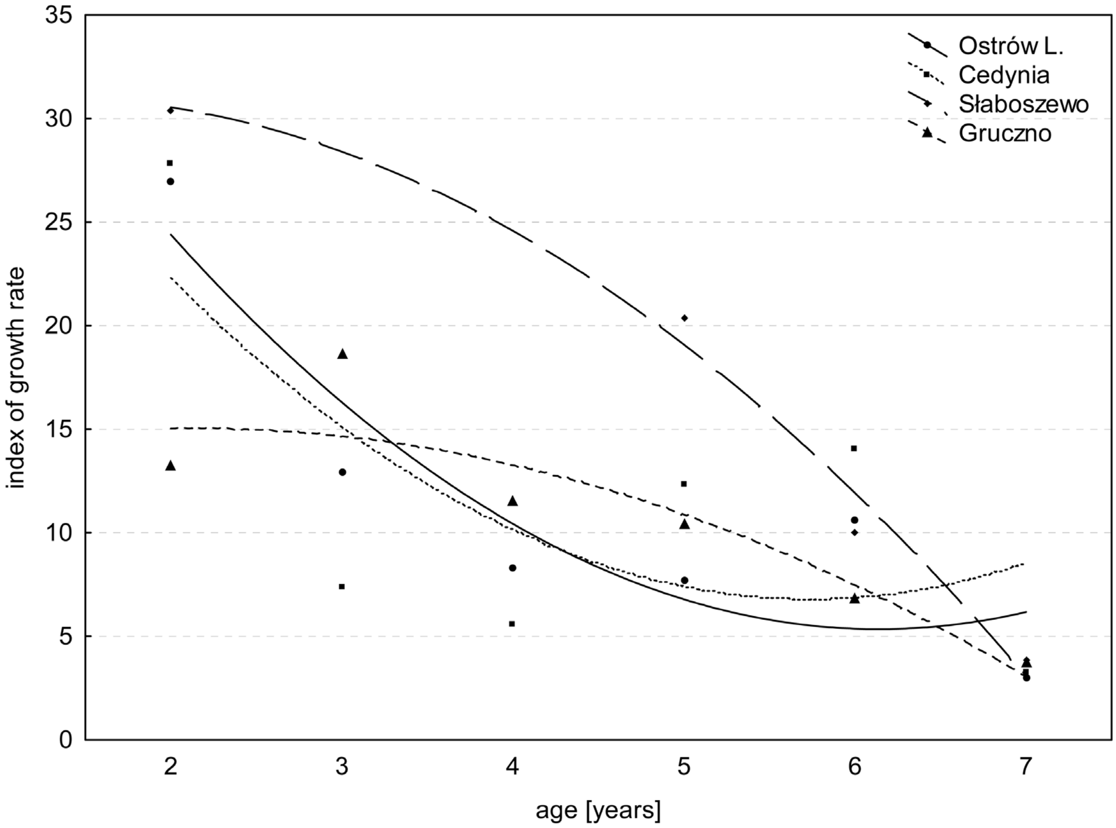
lower in the Ostrów Lednicki sample, contrary to enamel hypoplasia, scurvy and rickets. *Cribra orbitalia*, together with porotic hyperostosis, were until recently commonly regarded as caused by iron-deficiency anemia. Recently, Walker *et al.* (2009) denied this widespread opinion and presented the argumentation that nutritional megaloblastic anemia is more likely to develop porotic hyperostosis and that *cribra orbitalia* may additionally occur in response to other nutritional diseases as scurvy, rickets or traumatic injuries. They argue that the synergistic effects of nutrient-deficient diet, poor sanitary conditions, infectious diseases and behavior related to breastfeeding mode, may be involved in the etiology of both markers. The main causes of megaloblastic anemia are deficiencies of vitamins B12 and B9, that derive mainly from animal foods. Therefore this condition is likely to develop in populations with limited access to such products. On account of the capacity of vitamins B accumulation, children are at much greater risk than the adults. Factors associated with low values of vitamin B12 are also gastrointestinal parasite infections and poor sanitation (Walker *et al.* 2009). The inhabitants of Ostrów Lednicki likely suffered from gastrointestinal parasitic infections, which is evidenced by the finding of a cyst of *Echinococcus granulosus* (Gładykowska–Rzeczycka *et al.* 2003). Humans who do not follow basic hygiene practices become infected by this tapeworm through the alimentary tract and, as already mentioned, rather low sanitary conditions in the Ostrów Lednicki sample were suggested by archaeological data. The etiology of *cribra orbitalia* is presumed to be more complex than it is for porotic hyperostosis (Walker *et al.* 2009, Wapler *et al.* 2004, Ortner, Ericksen 1997). In the present study orbital roof porosity was recorded as *cribra orbitalia* when no signs of scurvy and rickets were found in "typical" of them bone regions. The prevalences of scurvy and rickets are, anyway, low in the examined sample and their values are almost the same within the populations. This supports the notion that since both indicators are related to dietary insufficiencies, they often co-occur in many populations.

On the basis of skeletal growth profiles and health indicators Ostrów Lednicki preadults seem to be quite well adapted to their environment. Higher level of femur growth starts to be apparent after the age of 8 years and is much more marked a few years later. However, different aging methods must be considered. Prior to 12 years of age dental method is widely applied, regarded as most reliable among morphological observations, since dental development remains under stronger genetic control and is less subject to environmental influences (Cardoso 2007, Saunders 2000). For older individuals bone fusion or diaphyseal measurements serve as aging methods, the pattern of which may change depending on the environmental conditions. There are also some other problems with age assessments of juveniles, for example related to unknown proportion of boys and girls and differential age they enter the pubertal spurt (Hoppa 1992, Lewis 2007). Therefore, the growth phenomena after the age of 12 years should be treated with caution. The growth rate curve of Ostrów Lednicki preadults shows a characteristic decrease after the 2nd year of life (Šereikiene, Jankauskas 2004), likely representing nutrition-infection interactions (King, Ulijaszek 1999) and slight acceleration after the 6th year, similarly to the Cedynia



Data on Cedynia, Slaboszcwo and Gruczno from Jerszynska (2004)

FIGURE 5. Skeletal growth profiles of femur in Polish medieval samples.



Data on Cedynia, Slaboszcwo and Gruczno from Jerszynska (2004)

FIGURE 6. Growth rate profiles of femur in Polish medieval samples.

individuals. The remaining two groups, especially late-medieval Słaboszewo, show a different pattern – the decline is more gradual with no growth recovery, and indicates that in this poor population the living conditions were unfavorable, but rather stable throughout the whole childhood period. Such notion is supported by archeological data that show differential status of the particular samples. It is evidenced that in the Middle Ages Cedynia and, particularly, Ostrów Lednicki sites, because of their location, role in the Polish state and the social position of the inhabitants, provided more beneficial conditions for the development of children. The socio-economic status of Gruczno was definitely lower, and the lowest was of Słaboszewo, rural site, where people lived in rather unchanging poor environmental and cultural circumstances.

From the data on the frequency of health markers by age categories in Ostrów Lednicki preadults it seems that the older individuals were more stressed than the younger ones. This may provide some support for the hypothesis that "better health makes for worse skeletons", meaning that only the individuals with skeletal traces of diseases were capable of respond to the stresses enough to survive to older age (Wood *et al.* 1992). However, the cases of both active and healed forms of *cribra orbitalia* were observed with similar frequency in younger and older preadults, so it seems that also children that died at earlier ages had sufficiently strong immune systems to survive the episodes of stress.

The comparison of health indicators in Ostrów Lednicki preadults and individuals from other European medieval samples shows medium or low frequency of lesions in the examined population. Data on all (or almost all) compared samples were accessible for *cribra orbitalia*, enamel hypoplasia, *periostitis* and endocranial new bone formation. In an early medieval site of Borovce (Slovakia) the frequency of *cribra orbitalia* in subadults aged 0–15 years was almost twice as in the sample of Ostrów Lednicki (Obertová, Thurzo 2004), while both in early medieval Mikulčice from Czech Republic (Velemínský *et al.* 2009) and in late medieval Serbian children from Stara Torina (Djuric *et al.* 2008) the prevalences were similar to the examined preadults. Enamel hypoplasia is quite prevalent in Ostrów Lednicki preadults as compared with other groups. In early medieval Slovakian preadults aged 0–14 years the frequency of enamel hypoplasia scored on all accessible deciduous and permanent teeth was half the value for the examined individuals (Obertová 2005). On the other hand, the Czech children from the Mikulčice agglomeration showed much higher incidence of hypoplastic defects, irrespective of the social composition of the studied groups (Trefný, Velemínský 2008). However, the data related to hypoplasia should be treated with caution, due to methodical differences in recording the defects. Some authors chose, for example, only particular tooth categories, most often mandibular canines or maxillary incisors, to record the enamel defects (Šlaus 2000) and some score all accessible tooth types (Bennike *et al.* 2005, Lewis 2002, Ribot, Roberts 1996). The incidence of Harris lines is highly differentiated, inter- and even intra-population, in the latter depending on the bones x-rayed. The frequency of the lines is quite high in the Ostrów Lednicki sample (only femora examined), but comparable to the medieval Czech sample of the Mikulčice agglomeration, when the lesion was observed in any of the studied bones: femur, tibia or humerus (Havelková *et al.* 2008). However, the analysis carried out separately for particular bones of the Czech children showed a considerable difference in the prevalence of the condition: almost 90% in tibiae and slightly more than 50% in femora (Havelková-Zítková *et al.* 2009).

In general, having in mind limitations of particular stress indicators in interpretation of past health (Lewis, Roberts 1997), it should be emphasized that the health status of the examined individuals aged 0–15 years was relatively high, and, in consequence, the whole population from which they derive, was rather well adapted to its living conditions.

CONCLUSIONS

The analysis of growth and health markers shows relatively medium severity of stressors, mainly of dietary and disease (infectious, parasitic) origin and, in consequence, rather good adaptation of the Ostrów Lednicki population to its environment. Patterns of skeletal indicators frequency and distribution likely reflect differentiation in living conditions of particular samples. The access to the information that derive from various sources (anthropological, archaeological, historical) makes it possible to obtain a reliable view of past populations. Using all available skeletal markers of growth and health status is highly recommended.

ACKNOWLEDGEMENTS

The author is very grateful to A. Wrzesińska and J. Wrzesiński from the Museum of the First Piast at Lednica for the access to the skeletal material of Ostrów Lednicki.

REFERENCES

BENNIKE P., LEWIS M. E., SCHUTKOWSKI H., VALENTIN F., 2005: Comparison of child morbidity in two contrasting medieval cemeteries from Denmark. *Amer. J. of Phys. Anthrop*. 128: 734–746.

BOGIN B., 1993: *Patterns of human growth.* Cambridge University Press, Cambridge.

BOGUWOLSKI R., HYSS L., 2005: *Biżuteria średniowieczna z cmentarzyska w Grucznie. Mittelalterlicher Schmuck aus dem Gräberfeld in Gruczno*. Muzeum w Grudziądzu, Grudziądz.

BUIKSTRA J. E., UBELAKER D., 1994: Standards for data collection from human skeletal remains. Proceedings of a seminar at the Field Museum of Natural History, Arkansas. *Archaeological Survey Research Series* 44.

CARDOSO H. F. V., 2007: Environmental effects on skeletal versus dental development: using a documented subadult skeletal sample to test a basic assumption in human osteological research. *Amer. J. of Phys. Anthrop*. 132: 223–233.

DAVIS A. P., 1996: *Targeting the vulnerable in emergency situations: Who is vulnerable?* Lancet 9031: 868–871.

DJURIC M., MILOVANOVIC P., JANOVIC A., DRASKOVIC M., DJUKIC K., MILENKOVIC P., 2008: Porotic lesions in immature skeletons from Stara Torina, late medieval Serbia. *Int. J. Ostearchaeology* 18: 458–475.

DRZYMAŁA S., MOCEK A., 1994: Przydatność rolnicza gleb Lednickiego Parku Krajobrazowego w aspekcie ochrony wód i krajobrazu. *Studia Lednickie* 3: 309–326.

EVELETH P. B., TANNER J. M., 1990: *Worldwide variation in human growth.* Cambridge University Press, Cambridge.

GOODMAN A. H., 1993: On the interpretation of health from skeletal remains. *Curr. Anthrop.* 34: 281–288.

FEREMBACH D., SCHWIDETZKY I., STLOUKAL M., 1980: Recommendations for age and sex diagnoses of skeletons. *J. of Hum. Evol.* 9: 517–549.

FILIPOWIAK W., 1966: *Cedynia w czasach Mieszka I.* Wydawnictwo Poznańskie, Poznań.

FLORKOWSKI A., KOZŁOWSKI T., 1993: Evaluating the skeletal age of children on the basis of bone size, *Przegląd Antropologiczny* 57: 71–86.

GŁADYKOWSKA-RZECZYCKA J., WRZESIŃSKA A., WRZESIŃSKI J., 2003: Rzadkie znalezisko torbieli pasożyta z wczesnośredniowiecznego cmentarzyska w Dziekanowicach, *Archeologia Polski* XLVIII: 57–74.

GOODMAN A. H., ROSE J. C., 1990: Assessment of systemic physiological perturbations from dental enamel hypoplasias and associated histological structures. Yearb. *Phys. Anthrop.* 33: 59–110.

GÓRECKI J., ŁASTOWIECKI M., WRZESIŃSKI J., 1994: Wczesnośredniowieczne budownictwo mieszkalne Ostrowa Lednickiego. *Studia Lednickie* 3: 21–45.

GÓRECKI J., WRZESIŃSKI J., 1991: *Badania podwodne Ostrowa Lednickiego.* Wydawnictwo Naukowe UAM, Poznań.

GRAUER A. L., 1993: Patterns of anemia and infection from medieval York, England. *Amer. J. of Phys. Anthrop.* 91: 203–213.

HAVELKOVÁ-ZÍTKOVÁ P., VELEMÍNSKÝ P., DOBISÍKOVÁ M., LIKOVSKÝ J., 2009: Harris lines in the non-adult Great Moravian population of Mikulčice (Czech Republik). *Acta Universitatis Carolinae* CLVI: 102–109.

HAVELKOVÁ P., VELEMÍNSKÝ P., LIKOVSKÝ J., DOBISÍKOVÁ M., 2008: Harris lines in the non-adult Great Moravian population from Mikulčice – the comparison of inhabitants of the castle and sub-castle area. In: P. Velemínský, L. Poláček (Eds): S*tudien zum Burgwall von Mikulčice.* Pp. 209–222. Archäologisches Institut der Akademie der Wissenschaften der Tschechischen Republik, Brno.

HENGEN O., 1971: Cribra orbitalia: pathogenesis and probable etiology. *Homo* 22: 57–75.

HOPPA R. D., 1992: Evaluating human skeletal growth: an Anglo-Saxon example. Internat. *J. of Osteoarchaeology* 2: 275–288.

HUMPHREY L. T., KING T., 2000: Childhood stress: a lifetime legacy. *Anthropologie* XXXVIII: 33–49.

JERSZYŃSKA B., 1991: Harris's lines and cribra orbitalia as indicators of stress in prehistoric human populations. *Variability and Evolution* 1: 105–112.

JERSZYŃSKA B., 2004: *Procesy wzrastania i rozwoju oraz ich uwarunkowania w średniowiecznych populacjach ludzkich.* UAM, Poznań.

KING S. E., ULIJASZEK S. J., 1999: Invisible insults during growth and development: contemporary theories and past populations. In: R. D. Hoppa, C. M. FitzGerald (Eds): *Human growth in the past. Studies from bones and teeth*. Pp. 161–182. Cambridge University Press, Cambridge, UK.

KOZŁOWSKI T., 1993: Charakterystyka urazów układu kostnego ludności pochowanej na cmentarzysku w Grucznie (XI–XIV w.). *Przegląd Antropologiczny* 56: 177–189.

LEWIS M., 2002: Urbanisation and child health in medieval and post-medieval England. *BAR British Series* 339, Archaeopress, Oxford.

LEWIS M. E., 2004: Endocranial lesions in non-adult skeletons: understanding their aetiology. *Int. J. Ostearchaeology* 14: 82–97.

LEWIS M. E., 2007: *The bioarchaeology of children. Perspectives from biological and forensic anthropology*. Cambridge University Press, Cambridge.

LEWIS M., ROBERTS C., 1997: Growing pains: the interpretation of stress indicators. *Internat. J. of Ostearchaeology* 7: 581–586.

ŁUBOCKA Z., 2003: Wyznaczniki stresów a środowisko życia wczesnośredniowiecznej populacji z Ostrowa Lednickiego. *Monografie Zakładu Antropologii PAN*, Wrocław.

MAKOWIECKI D., 2001: Hodowla oraz użytkowanie zwierząt na Ostrowie Lednickim w średniowieczu. *Studium archeozoologiczne*. Biblioteka Studiów Lednickich 6, Poznań.

MALINOWSKA-ŁAZARCZYK H., 1982: *Cmentarzysko średniowieczne w Cedyni.* Muzeum Narodowe w Szczecinie, 7–79.

MENSFORTH R. P., LOVEJOY C. O., LALLO J. W., ARMELAGOS G. J., 1978: The role of constitutional factors, diet, and infectious disease in the etiology of porotic hyperostosis and periosteal reactions in prehistoric infants and children. *Med. Anthropol.* 2: 1–59.

MILECKA K., 1994: Rezultaty badań przyrodniczo-archeologicznych przeprowadzonych na wczesno-średniowiecznym moście/grobli w Gieczu, gm. Dominowo, stan. 2. Badania palinologiczne osadów biogenicznych rdzenia G-4/90. *Studia Lednickie* 3: 216–221.

OBERTOVÁ Z., 2005: Environmental stress in the early medieval Slavic population at Borovce (Slovakia). *Homo* 55: 283–291.

OBERTOVÁ Z., THURZO M., 2004: Cribra orbitalia as an indicator of stress in the early medieval Slavic population from Borovce (Slovakia). *Anthropologie* XLII: 189–194.

ORTNER D. J., BUTLER W., CAFARELLA J., MILIGAN L., 2001: Evidence of probable scurvy in subadults from archeological sites in North America. *Amer. J. of Phys. Anthrop.* 114: 343–351.

ORTNER D. J., ERICKSEN M. F., 1997: Bone changes in the human skull probably resulting from scurvy in infancy and childhood. *Int. J. of Osteoarchaeology* 7: 212–220.

ORTNER D. J., KIMMERLE E.H., DIEZ M., 1999: Probable evidence of scurvy in subadults from archeological sites in Peru. *Amer. J. of Phys. Anthrop.* 108: 321–331.

PIONTEK J., 1977: Średniowieczne Cmentarzysko w Słaboszewie koło Mogilna: analiza wymieralności. *Przegląd Antropologiczny* 43: 37–53.

PIONTEK J., 1981: Biologiczna charakterystyka średniowiecznej populacji wiejskiej ze Słaboszewa, woj. bydgoskie. In: A. Malinowski (Ed.): *Źródła do badań biologii i historii populacji słowiańskich.* Pp. 39–83. Uniwersytet im. Adama Mickiewicza w Poznaniu, Seria Antropologia nr 10, Poznań.

PIONTEK J., JERSZYŃSKA B., 1993: Częstość występowania linii Harrisa i cribra orbitalia w trzech populacjach średniowiecznych z terenu Polski. In: J. Gładykowska-Rzeczycka (Ed.): *Człowiek w czasie i przestrzeni.* Pp. 381–385. Wydawnictwo Gdańskie, Gdańsk.

PIONTEK J., JERSZYŃSKA B., NOWAK O., 2001: Harris lines in subadult and adult skeletons from the mediaeval cemetery in Cedynia, Poland. *Variability and Evolution* 9: 33–43.

PIONTEK J., KOZŁOWSKI T., 2002: Frequency of cribra orbitalia in the subadult medieval population from Gruczno, Poland. *Int. J. of Osteoarchaeology* 12: 202–208.

PIONTEK J., SEGEDA S., JERSZYŃSKA J., 2001: Cribra orbitalia in medieval populations from Ukraine. *Anthropologie* XXXIX: 173–179.

RIBOT I., ROBERTS C., 1996: A study of non-specific stress indicators and skeletal growth in two mediaeval subadult populations. *J. of Archaeol. Sci.* 23: 67–79.

SAUNDERS S. R., 2000: Subadult skeletons and growth-related studies. In: A. Katzenberg, S. R. Saunders (Eds): *Biological anthropology of the human skeleton.* Pp. 135–161. Wiley Liss, Inc., New York.

SAUNDERS S. R., BARRANS L., 1999: What can be done about the infant category in skeletal samples?. In: R. D. Hoppa, C. M. FitzGerald (Eds): *Human growth in the past. Studies from bones and teeth*. Pp. 183–209. Cambridge University Press, Cambridge, UK.

SCHEUER L., BLACK S., 2000: *Developmental juvenile osteology.* Elsevier Academic Press, Oxford, UK.

SCHEUER L., BLACK S., 2000: *The juvenile skeleton.* Elsevier Academic Press, Oxford, UK.

STECKEL R. H., LARSEN C. S., SCIULLI P.W., WALKER P. L., 2006: Data Collection Codebook. The Global History of Health Project, http://global.sbs.ohio-state.edu/new_docs/Codebook-06-28-06.pdf.

STEINBOCK R. T., 1976: Paleopathological diagnosis and interpretation. *Bone diseases in ancient human populations.* Pp. 170–191. Springfield, C. C. Thomas.

STLOUKAL M., HANÁKOVÁ H., 1978: Die Länge der Längsknochen altslawischer Bevölkerungen unter besonderer Berücksichtigung von Wachstumsfragen. *Homo* 29: 53–69.

STUART-MACADAM P., 1991: Anaemia in Roman Britain. *BAR International Series* 199, Archaeopress, Oxford.

ŠEREIKIENE I., JANKAUSKAS R., 2004: Lithuanian children's growth patterns in the past – an updated medieval sample. *Papers on Anthropology* XIII: 226–238.

ŠLAUS M., 2000: Biocultural analysis of sex differences in mortality profiles and stress levels in the late medieval population from Nova Rača, Croatia. *Amer. J. of Phys. Anthrop.* 111: 193–209.

ULIJASZEK S., 1998: Long-term consequences of early environmental influences. In: S. J. Ulijaszek, F. E. Johnston, M. A. Preece (Eds): *The Cambridge Encyclopedia of Human Growth and Development.* Pp. 417–418. Cambridge University Press, Cambridge.

TOBOLSKI K., 1991: Wstęp do paleoekologii Lednickiego Parku Krajobrazowego. *Biblioteka studiów lednickich* 6, UAM, Poznań.

TREFNÝ P., VELEMÍNSKÝ P., 2008: Linear enamel hypoplasia in an Early Medieval population of Great Moravia. In: P. Velemínský, L. Poláček (Eds.): *Studien zum Burgwall von Mikulčice.* Pp. 141–149. Archäologisches Institut der Akademie der Wissenschaften der Tschechischen Republik, Brno.

VELEMÍNSKÝ P., DOBISÍKOVÁ M., STRÁNSKÁ P., TREFNÝ P., LIKOVSKÝ J., 2009: The health status of the Early Medieval population of Greater Moravia in relations to social and economic structures. *Acta Universitatis Carolinae* CLVI: 91–101.

WALKER P. L., BATHURST R. R., RICHMAN R., GJERDRUM T., ANDRUSHKO V. A., 2009: The causes of porotic hyperostosis and cribra orbitalia: A reappraisal of the iron-deficiency-anemia hypothesis. *Amer. J. of Phys. Anthrop.* 139: 109–125.

WAPLER U., CRUBÉZY E., SCHULTZ M., 2004: Is cribra orbitalia synonymous with anemia? Analysis and interpretation of cranial pathology in Sudan. *Amer. J. of Phys. Anthrop*. 123: 333–339.

WOLAŃSKI N., 1975: *Metody kontroli i normy rozwoju dzieci i młodzieży.* Państwowy Zakład Wydawnictw Lekarskich, Warszawa.

WOOD J., MILNER G. R., HARPENDING H. C., WEISS K. M., 1992: The Osteological Paradox. *Curr. Anthrop*. 33: 343–370.

WRZESIŃSKA A., WRZESIŃSKI J., 2005: *Czytanie z kości.* Muzeum Pierwszych Piastów na Lednicy, Lednica.

Marta Krenz-Niedbała
Department of Human Evolutionary Biology
Institute of Anthropology
Faculty of Biology
Adam Mickiewicz University
Poznań, Poland
E-mail: martak@amu.edu.pl