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Frequency and chronological distribution of linear enamel hypoplasia (LEH) in the Late Neolithic and Early Bronze Age population from Żerniki Górne (Poland) – preliminary report

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Abstract: Linear enamel hypoplasia (LEH) is treated as a nonspecific indicator of stress, but even so, many authors consider it the most reliable tool stress in anthropological research. Its analysis allows the reconstruction of health related to the socio-economic status of the group. This study documents and interprets patterns of LEH in Żerniki Górne (Poland), a settlement which was functional in the Late Neolithic and the Early Bronze Age. We examined two successive cultures: the Corded Ware Culture (CWC; 3200–2300BC) and the Trzciniec Culture (TC; 1500–1300BC). In total, there were 1486 permanent teeth (124 adult individuals). The frequency of LEH in the examined cultures shows a small rising trend. In these series from Żernik Górne, males showed a higher occurrence of LEH (16.5%) than females (13.4%). The earliest LEH appeared at similar ages at about 2.0/2.2 years and the last LEH occurred at about 4.2 years of age in both cultures. However, it is worth noting that periods associated with physiological stress were more common but not very long (four months on average) in the CWC. Longer stress periods (nine months on average) were associated with the TC.

Key words: enamel hypoplasia, Żerniki Górne, Corded Ware Culture, Trzciniec Culture

An important issue in prehistoric and historical research is the assessment of the biological condition of the population. The source of this information is the assessment of physiological stress indicators. Poor living conditions cause a reaction of the body, which can manifest itself in both the bone (e.g., *porotic hyperostosis, cribra orbitalia*, Harris lines, body height) and dental material (e.g., enamel hypoplasia, dental caries, periodontal disease). Attempts to assess living conditions are often made in anthropological studies (e.g., Piontek and Kozłowski 2002; Kujanová et al. 2008; Liebe-Harkort 2012). It seems, howev-

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er, that special attention is given to the Neolithic populations because of the significant cultural transformation from food collection to food production (e.g., Larsen 1995; Eshed et al. 2010; Molnar et al. 2011; Köhler et al. 2012). Contemporary studies in Central Europe (e.g. Poland: Osłonki, Złota, Brześć Kujawski, Samborzec, Bronocice) prove that the directions of these changes are rather universal. There are source of evidences for stature reduction (length of long bones) (e.g. Gleń-Haduch 1995; Larsen 1995; Piontek 1999; Piontek and Vancata 2002), or increases in LEH (e.g., Gleń-Haduch 1995; Krenz-Niedbała 1999, 2000, 2001; Haduch 2002) with the development of agriculture strategy.

The assessment of physiological stress on bone material (e.g., *cribra orbitalia* and length of long bones) is particularly interesting, but due to the high fragmentation of archaeological material it is not always possible to test these stress indicators (e.g., Gleń-Haduch et al. 1997; Piontek 1999; Keenleyside and Panayotove 2006). However, odontological material is usually well preserved in archaeological sites, so studies of such material are frequently used in anthropological research (e.g., Berbesque and Doran 2008; Jackes 2009). Odontological research can provide much valuable information, facilitating improved knowledge of health conditions and understanding of the direction of biological transformations within a given population over the centuries. This is possible thanks to the morphological reaction of hard dental tissues to changing living conditions.

The most common indicator used in such research is enamel hypoplasia. It is the most common irregularity observed in the teeth, and is expressed as lines, grooves, or pits resulting from the death or reduced functioning of the ameloblasts and a consequent failure in the formation of the enamel matrix (e.g., Herring et al. 1998; Hillson and Bond 1997; Hillson 2002). It is treated as a nonspecific indicator of stress, but, even so, many authors consider it the most reliable tool in anthropological researches (e.g., Larsen 2003; Boldsen 2007; Griffin and Donlon 2009; Temple 2010). In the etiology of hypoplastic changes in tooth enamel, three main classes of factors have been listed: general (systemic), local, and genetic. The presented characteristics of the distinct types of enamel hypoplasia are an important prerequisite for attempts aimed at reconstructing the level of health and, indirectly, also the economic and social status of the examined population. In this respect, the changes classified as general-systemic hypoplasia are most relevant (Hillson and Bond 1997; Hillson 2002; King et al. 2005; Ritzman et al. 2008).

The relationship between oral health and social status has been documented in archaeological settings, particularly during the transformation from foraging to agriculture (e.g., Larsen 1995, 2003; Wright 1997; Krenz-Niedbała 2001; Temple 2010).

The present paper focuses on linear enamel hypoplasia (LEH), which was observed in the populations of Żerniki Górne (Poland) representing two cultures dated in the Late Neolithic (Corded Ware Culture – CWC) and Early Bronze Age (Trzciniec Culture –TC).

Żerniki Górne is one of the more important archaeological locations of southeastern Poland. It is a village situated on a plateau of loess in the Busko-Zdrój district (50°28'N, 20°48'E) (Fig. 1). The CWC represents the last part of the

Stone Age. It developed between 3200 and 2300BC, although ^{14}C analysis of 10 samples allowed us to date the oldest part of the cemetery in Żerniki Górne as 4160±50 to 3900±55 BP (Kempisty and Włodarczyk 1996; Wierzbicki 1999). The younger culture found in Żerniki Górne (TC) flourished between 1500 and 1300 BC.

The lifestyle of the CWC period is still the subject of controversy, because the CWC settlement is not well-known. Generally, researchers propose two hypotheses. According to one, the people of the CWC relied on a mixed or semi-nomadic economy. This lifestyle included farming, pasturing, and hunting (Gleń-Haduch 1995; Janowska 1999; Piontek 1999). It is possible that hunting for animals along the way compensated for losses of pasture animals and resultant food shortages. The small number of remains of pigs further strengthens the hypothesis of a wandering lifestyle (Kruk 1980; Kruk and Milisauskas 1999). According to the second hypothesis the economy of the CWC was based on typical agriculture, suggesting that these were predominantly sedentary communities. Archaeobotanical research confirms the presence of barley seeds (*Hordeum vulgaris*), wheat grains (*Triticum monococum*), oats (*Avensa sp.*), lentils (*Lens esculenta*), and peas (*Pisum sativium*) (Tunia 1986; Kruk and Milisauskas 1999; Jankowska 1999). Still, it is hard to decide explicitly which of the hypotheses is more reliable. The TC is associated with a typical agricultural and settlement lifestyle (Gleń-Haduch 1995; Kardow and Machnik 1997). Archaeozoological research has proved that the people of the TC bred animals and were involved in farming (remains of corn, signs of ploughing), hunting, and gathering (accumulation of sea-shells and turtle hulls).

Figure 1. Location of Żerniki Górne

The frequency of LEH increased in other series from Poland (e.g., Osłonki, Złota, Słonowice) following the transformation to intensive agriculture (Gleń-Haduch 1995; Krenz-Niedbała 1999; 2000; 2001; Haduch 2002). According to these observations, we can put forward the following hypothesis: if the strategy of the CWC population was based on typical farming, the frequency of LEH should be similar to that among the TC population, whose agricultural and settlement lifestyle are confirmed by the archaeological sources (Bahn 1992; Kardow and Machnik 1997). The difference in the patterns of lifestyle connected with economic change allows us to argue that in these periods LEH should be different as its frequency should be higher in the period associated with typical agriculture (TC) than in the period associated with the mixed or semi-nomadic lifestyle (CWC).

Materials and methods

This study concerns the dentition of 124 adult individuals (37 from the CWC; 87 from the TC) (Table 1).

In our analyses we used 1486 permanent teeth (M3 – 110, M2 – 229, M1 – 245; P2 – 198; P1 – 177, C – 243, I2 – 154, I1 – 130) (Table 2). Only those individuals where it was possible to determine sex and age were selected for analysis. The remains are stored in the State Archaeological Museum in Warsaw (Poland).

Before the study, every tooth was cleaned with a brush and, when necessary, washed in alcohol to remove the remaining grime. Enamel defects were observed according to a macroscopic method; we used a CL-D 10× magnifying glass with an additional source of light. At this stage of the project we could not conduct scanning electron microscope (SEM) analyses. The research was conducted only on those materials which had at least two teeth with defects. It is assumed that local hypoplasia is not a population-wide factor (Suckling et al. 1987; Zilberman et al. 2004).The defects were then organized with the use of the Developmental Defects of Enamel Index (DDE): 0 – normal, 1 and 2 – opacity (white or brown patches on the surface of the enamel), 3 – pits, 4 – horizontal grooves and/or lines (LEH), 5 – vertical grooves and/or lines, 6 – missing enamel on a certain part of the surface (FDI 1982). But in this study we focused only on LEH (according to DDE No. 4). The frequency of LEH was calculated on the basis of all teeth (posterior and anterior) (Table 2).

The location of LEH makes it possible to establish the age when these defects occurred, using the developmental standards of Reid and Dean (2000; 2006). This method involves the allocation of hypoplastic defects within a broad developmental phase (the rate of enamel growth is not constant but decreases from the tip to the cervical margin), and it eliminates the need to correlate the specific age with any given hypoplastic defects. Our analyses were narrowed down to include only the anterior teeth which were well preserved (Goodman and Rose 1990; Guatelli-Steinberg 2003).Some defects are most frequently found in the upper part of the crown. So, in the analysis of LEH, the teeth whose crowns were excessively damaged were omitted in order

Table 1. Total number of individuals from Żerniki Górne

Period	N individuals			N teeth		
	Males	Females	Total	Male	Female	Total
Corded Ware Culture	23	14	37	382	168	550
Trzciniec Culture	50	37	87	538	398	936
Total	73	51	124	920	566	1486

Table 2. Distribution of study teeth from Żerniki Górne according to sex, type of tooth and jaw

Period	Sex	Maxilla								Mandible							
		M3	M2	M1	P2	P1	C	I2	I1	M3	M2	M1	P2	P1	C	I2	I1
Corded Ware Culture	Male	17	38	35	25	22	34	19	24	12	30	27	24	17	23	25	10
	Female	12	12	17	13	11	14	8	12	4	9	12	10	10	13	2	9
Trzciniec Culture	Male	12	32	43	40	31	50	25	27	21	49	46	36	32	48	31	15
	Female	15	30	32	30	33	39	27	20	17	29	33	20	21	22	17	13
	Total	56	112	127	108	97	137	79	83	54	117	118	90	80	106	75	47

Table 3. Number of anterior teeth with LEH used for reconstruction of the age

Period	Maxilla			Mandible		
	I1	I2	C	I1	I2	C
Corded Ware Culture	8	3	15	3	7	12
Trzciniec Cultur	12	9	30	4	10	25

to avoid false results. We analysed teeth which did not exceed No. 3 according to Smith's scale (1984). We selected 138 anterior teeth with LEH. They belonged to 55 individuals of both sexes (Table 3). Crown heights were measured with a caliper (0.01 mm) from the cemento–enamel junction (CEJ) to the apex on the vertical plane bisecting the labial surface of the teeth. These measurements were converted into the approximate ages of development based on the timing of enamel formation. We used the standards for northern European populations (Reid and Dean 2006).

The Chi-square test was used to explain the significant differences in LEH tooth frequencies between the CWC and TC, or, more simply, to account for the presence or absence of enamel hypoplasia independently of temporal periods. The results were classified as statistically significant if $p \leq 0.05$.

Results

The first step was to estimate the frequency of LEH in the population of Żerniki Górne. Among the 124 individuals examined, LEH was found in 68, which means that the defect affected 55% of the population.LEH affected 51.3% (19/37)of the individuals from the CWC period and 56.3% (49/87) from the TC period. However no statistically significant difference between the periods was observed.

In the specimens examined, LEH occurred most often on the lower and upper canines, followed by the upper and lower incisors. Among the posterior teeth, LEH was observed especially on the premolars (Table 4).

Out of 1486 specimens examined, LEH occurred in 228 cases, which means that 15% of the teeth were affected. Since the research was conducted on the populations that lived in Żerniki Górne during two different periods, it was interesting to consider the differences between the numbers of teeth affected by LEH. A rising trend is visible, with a smaller frequency being found among the people of the CWC and a higher frequency in the TC. However the difference in the occurrence of LEH between the two cultures does not seem to be statistically significant ($\chi^2=1.05$, df=1, p=0.30) (Table 5).

LEH occurs more often in males (15%) than females (10%) in the CWC. But the observed difference is not statistically significant ($\chi^2=1.79$, df=1, p=0.18). A similar finding in the TC enamel hypoplasia was observed in 17% of males and 14% of females ($\chi^2=1.05$, df=1, p=0.30) (Table 5).

The next step in the research was to perform a reconstruction of the age when LEH emerged on anterior teeth. LEH first occurred most often on central maxillary incisors in the CWC at about 2.4–2.9 years of age. LEH was next observed in the CWC between 3.4 and 3.9 years of age. In the TC the LEH on central maxillary incisors was observed at about 2.0–2.9 years of age. LEH on lateral maxillary incisors was formed in both cultures between 2.4 and 2.7. With regard to the CWC, the in-

Table 4. Żerniki Górne: number of teeth and LEH distribution by tooth type

Period	Maxilla								Mandible							
	M3	M2	M1	P2	P1	C	I2	I1	M3	M2	M1	P2	P1	C	I2	I1
Corded Ware Culture	2/27	6/44	4/48	1/37	1/32	15/33	3/24	10/26	0/16	2/37	2/37	4/30	3/24	12/24	9/18	3/16
Trzciniec Culture	0/27	4/58	4/71	7/63	7/57	33/56	12/40	16/31	0/38	5/73	2/77	9/47	8/45	28/42	10/38	6/22

Table 5. Żerniki Górne: number of teeth with LEH stratified by sex

Period	Total					Male			Female				
	N	n LEH	%	χ^2	p	N	n LEH	%	N	n LEH	%	χ^2	p
Corded Ware Culture	550	77	14.0	1.05	0.30	382	59	15.4	168	18	10.7	1.79	0.18
Trzciniec Culture	936	151	16.1			538	93	17.2	398	58	14.5	1.05	0.30
Total	1486	228	15.3			920	152	16.5	566	76	13.4	2.35	0.12

Table 6. Number of horizontal lines and approximate age (years) at which LEH appeared on the anterior teeth

Period/Approximate Age (years)		1.5–1.9	2.0–2.4	2.5–2.9	3.0–3.4	3.5–3.9	4.0–4.4	χ^2	p
Corded Ware Culture	n	2/83	17/83	33/83	11/83	15/83	5/83	33.37	<0.00
	%	2.4	20.5	40.0	13.2	18.0	6.0		
Trzciniec Culture	n	5/129	18/129	33/129	26/129	30/129	17/129	5.95	0.20
	%	3.8	14.0	25.5	20.1	23.2	13.1		

itial factors which influenced damage to ameloblasts in maxillary canines were estimated to occur at 2.2 to 2.4 years and later at 2.7 to 3.0 years. However in the TC only one defect was observed at about 3.0–3.8 years. The same analysis was estimated on the basis of mandibular canines: the peaks of LEH correspond with the following ages: 2.3–2.7 and 3.6–4.2 years in the CWC and 3.1–4.2 years in the TC. On lateral mandibular incisors the LEH was formed in the CWC between 2.4 and 2.8 and in the TC 2.8–3.3 years of age.

The earliest LEH appeared at similar ages of about 2.0/2.2 years and the last LEH occurred at about 4.2 years in both cultures. However, it is worth noting that periods associated with physiological stress were more common but not very long (four months on average) in the CWC. Longer periods of stress (nine months on average) were identified in the TC. In general, LEH occurs on the anterior teeth in the CWC at about 2.5–2.9 years of age. Moreover, in the CWC we observed the next damage to ameloblasts at the age of about 3.5–3.9 years. In the TC we observed only one, long period of stress, which started at about 2.5 years and lasted about fourteen months, finishing at about 3.9 years of age (Table 6).

Discussion

The frequency of LEH in the examined cultures shows a small rising trend (Table 5). However, it is difficult to provide an explicit interpretation of the lack of any statistical significance. It is obvious that the greater frequency of LEH indicates an increase in physiological stress (e.g., Goodman and Armelagos 1988; Hillson and Bond 1997; Hillson 2002; Larsen 2003; Temple 2010). It is worth noticing that a rise in the frequency of enamel hypoplasia has also been found in other comparative studies of the CWC with the Lengyel Culture, which is associated with farming (e.g., Krenz-Niedbała 1999; 2000; 2001). A rising trend can also be observed in the Neolithic and Early Bronze samples from Terento (Italy). The investigation of the LEH showed an increased frequency of enamel disruption from the Neolithic to the Early Bronze Age population (Cucina 2002). Generally, the rise of LEH can be explained, paradoxically speaking, by the "invention" of the sedentary way of life. The populations which decided to become farming societies limited their meat consumption in favour of cereal products. Human communities which relied on a mixed economy had many different possibilities for obtaining food (farming, pasturing, and hunting). In case one of these elements were to fail, there was always an alternative way of getting food. In the farming societies, on the other hand, both men and women took part in farming and breeding, and therefore the whole population suffered from food shortages when there were bad crops or natural disasters. Moreover, the sedentary way of life resulted in a higher population density. This created favourable conditions for pathogens to cause various diseases. These conditions could include factors such as accumulated litter (cholera, typhoid), contact with domesticated animals (aphthosa, anthrax, tuberculosis), or even the irrigation and artificial fertilization of fields (trichinosis, echinococcosis) (Larsen 1995; Armelagos et al. 1996; Aufderheide and Rodríguez-Martín 2008; Temple 2010). However, we did not observe significant differences in the frequency of LEH between the groups from Żernik Górne. This means that the economies of the CWC and TC were not significantly different. A small, but not statistically significant, difference in the frequency of LEH may suggest that the economic changes occurring during this time were not sufficiently stressful to cause a dramatic deterioration in health in the TC. But we should remember that our interpretation has relied on a limited number of individuals.

LEH analysis is often connected with sexual dimorphism (e.g., Guatelli-Steinberg and Lukacs 1999; Hillson 2002; Bonfiglioli et al. 2003; Larsen 2003; Berbesque and Doran 2008). Sex differences in the frequency of LEH are highly variable. The differences between males and females are usually explained by means of cultural factors or biological evidence. The former may include favouring a particular sex-group, which basically involves better care-giving by parents and locals, or better nutritional conditions (including longer breastfeeding). Cultural influence may therefore weaken the stressing factors that cause enamel hypoplasia (Guatelli-Steinberg and Lukacs 1999).This explanation can be found in Goodman, whose research was based on children from Solis (Mexico) (Goodman et al. 1987). Similar arguments are provided by May and co-authors (1993), who reported that girls in contemporary Guatemala have a higher frequency of enamel hypoplasia than boys. The authors connect this phenomenon with a cultural factor – the preference for a son within the family. The biological explanation for the difference in the frequency of LEH, on the other hand, is based on the assumption that male organisms have a higher eco-sensitivity (vulnerability) to environmental stimuli. This means that boys are more susceptible to food shortages (which are stress factors causing enamel hypoplasia). While female organisms are less susceptible to adverse factors due to procreative functions: pregnancy, lactation, and care for the offspring (Hoyenga and Hoyenga 1982; Guatelli-Steinberg and Lukacs 1999). Such an explanation can be formulated on the basis of the evidence found in the Pada cemetery (Estonia), dated at the Late Iron Age. Men buried there had suffered from LEH more often than the females had. A higher social status of the female in Estonia could account for the lower frequency of metabolic stress among the girls (Limbo 2006). However, most of the research conducted on both historical and modern populations shows a tendency for one of the sexes to suffer from LEH more often; the differences, though, are not statistically relevant (e.g., Henneberg and Henneberg 1989; Guatelli-Steinberg and Lukacs 1999; Tomczyk et al. 2007). The lack of statistical significance makes it difficult to construct a reliable and definite model of dependency of the occurrence of the enamel hypoplasia on sex. This is also true for the population of Żerniki Górne; in the samples studied, we observed a tendency, albeit statistically insignificant, toward a higher LEH in males than in females in both cultures. This is also confirmed by other studies that have compared the populations of the CWC (Żerniki Górne and Złota) and the Lengyel Culture (Osłonki) from Poland (Krenz-Niedbała 1999; 2001).

LEH is most common on anterior teeth, and this fact was observed in both populations from Żerniki Górne. It corresponds with our knowledge about the times of the mineralization processes, which are different for different types of teeth (e.g., Hillson and Bond 1997; Liversidge 2000; Berbesque and Doran 2008).

Generally speaking, the CWC population tended to show a shorter duration (four months on average) of physiological stress, in contrast to the TC, for whom stressful events lasted longer (nine months on average). It is difficult to explain this phenomenon clearly, but it could be connected with deteriorations in living conditions. The intensification of agriculture might have led to bad health of the population (increase in population density) and epidemiological consequences. It might mean that the economic strategy of the CWC provided the local population with better protection from environmental disturbances than the later strategy of the TC. Probably the economy of the population from the CWC was not based on typical farming but was rather a mixed economy. Combining farming, pasturing, and hunting as a strategy for producing food minimized the risk of famine in the case of drought or other environmental disruptions (Gleń-Haduch 1995; Janowska 1999; Piontek 1999).

Some anthropological studies suggest that the enamel hypoplasia which occurs between the ages of two and four years in archaeological samples should be connected with the negative effects of weaning (Armelagos et al. 1996; Wright 1997; Herring et al. 1998; Bonfiglioli et al. 2003). This is a dangerous period of childhood and very often has some impact on the distribution of dental lesions. Breast milk is a significant component of diet and helps to develop the child's immunological system. However, this conclusion could also be called into doubt. Firstly, there are limitations concerning inferring the weaning age in past populations based on the occurrence of LEH. As we know, enamel hypoplasia has a number of causes, and is therefore a nonspecific stress indicator. Secondly, one ought to remember that weaning is not an abrupt event but rather a gradual process connected with the slow introduction of solid food (Larsen 1995; Wright 1997; Villalpando 2001; Marlowe 2005; Clayton et al. 2006). So, some authors doubt whether weaning stress could lead directly to LEH; thus in the end it may prove to be coincidental rather than factual (Katzenberg et al.1996; Larsen 2003). It is obvious that weaning practice depends on many factors, such as socioeconomic status, health of the woman, region, and local habits. Despite this, the samples from the CWC and TC exhibit a similar pattern of the earliest LEH distribution. The earliest defects appeared in both cultures at a similar age (2.0–2.2 years). If we accept the thesis that the earliest defects are a result of weaning stress, we can suggest analogous environmental adaptations. As is well known, in many hunter-gatherer populations weaning took place between three and four years of age (Goodman et al. 1984; Villalpando 2001; Marlowe 2005; Clayton et al. 2006). However, the weaning period shortened in agricultural and industrial populations. It is therefore unlikely that the CWC culture represented a typical hunting-gathering economy. This means that the CWC strategy relied rather on a mixed economy which transformed to intensive agriculture in the TC. Still, the results still need to be supported by isotopic research.

Conclusions

The results presented above allow us to formulate the following conclusions: i) There is a small rising trend in the frequency of LEH, but it appears that the economic changes occurring at this time were not sufficiently stressful to cause a dramatic deterioration in health in the TC. ii) The lack of statistical significance makes it difficult to construct a reliable and definite model of dependency of the occurrence of the enamel hypoplasia on sex. iii) The shorter duration of physiological stress in the CWC may suggest that the local population was better protected against environmental disturbances than later in the TC.

Authors' contribution

JT conceived of the paper aim and design, served as principal investigator for the research project, wrote the draft and approved the final manuscript; MTG served as an investigator for the project and was involved in drafting the manuscript; ZM performed statistical analyses, analyzed data and drafted the manuscript. All authors contributed to approved, final version of the manuscript.

Conflicting interests

The authors declare that they have no conflicts of interest in the research.

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References

Armelagos GJ, Barnes KC, Lin J. 1996. Disease in human evolution: the re-emergence of infectious disease in the third epidemiological transition. AnthroNotes. National Museum of Natural History Bulletin for Teachers 18(3).

Aufderheide AC, Rodríguez-Martín C. 2008. The Cambridge encyclopedia of human paleopathology. Cambridge: Cambridge University Press.

Bahn P. 1992. Dictionary of archaeology. Glasgow: Harper Collins Publishers.

Berbesque JC, Doran GH. 2008. Brief communication: physiological stress in the Florida archaic – enamel hypoplasia and patterns of developmental insult in Early North American hunter-gatherers. Am J Phys Anthropol 136:351–56.

Boldsen JL. 2007. Early childhood stress and adult age mortality – a study of dental enamel hypoplasia in teeth Medieval Danoish village of Tirup. Am J Phys Anthropol 132:59–66.

Bonfiglioli B, Brasili MG, Belcasreo MG. 2003. Dento-alveolar lesions and nutritional habits of a Roman Imperial age population (1st–4th c. AD): Quadrella (Molise, Italy). J Comp Hum Biol 54:36–56.

Clayton F, Sealy J, Pfeiffer S. 2006. Weaning age among foragers at Matjes River Rock Shelter, South Africa, from stable nitrogen and carbon isotope analysis. Am J Phys Anthropol 129:311–17.

Cucina A. 2002. Brief communication: diachronic investigation of linear enamel hypoplasia in prehistoric skeletal samples from Trentino, Italy. Am J Phys Anthropol 119:283–87.

Eshed V, Gopher A, Pinhasi R, Hershkovitz I. 2010. Paleopathology and the origin of agriculture in the Levant. Am J Phys Anthropol 143:121–33.

Fédération Dentaire International. 1982. An epidemiological index of developmental defects of dental enamel (DDE Index). Int Dent J 32:159–67.

Gleń-Haduch E. 1995. Biological status analysis of the Neolithic and early Bronze Age populations from WyżynaMałopolska. In: J Schmager, editor. Prace Zakładu Antropologii Uniwersytetu Jagiellońskiego. Kraków: Wydawnictwo UJ. 115–39.

Gleń-Haduch E, Szostek K, Głąb H. 1997. Cribra orbitalia and trace element content in human teeth from Neolithic and Early Bronze Age graves in southern Poland. Am J Phys Anthropol 103:201–07.

Goodman AH, Armelagos GJ, Rose JC. 1984. The chronological distribution of enamel hypoplasia from prehistoric Dickson Mounds populations. Am J Phys Anthropol 65:259–66.

Goodman AH, Allen LH, Hernandez GP, Amador A, Arriola LV, Chavez A, et al. 1987. Prevalence and age at development of enamel hypoplasia in Mexican children. Am J Phys Anthropol 72:7–19.

Goodman AH, Armelagos GJ. 1988. Childhood stress and decreased longevity in a prehistoric population. Am Anthropol 90:936–44.

Goodman AH, Rose JC. 1990. Assessment of systematic physiological perturbations from dental enamel hypoplasias and associated histological structures. Yearbook Phys Anthropol 33:59–110.

Griffin RC, Donlon D. 2009. Patterns in dental enemel hypopasia by sex and age at death in two archaeological populations. Arch Oral Biol 54S:93–100.

Guatelli-Steinberg D, Lukacs JR. 1999. Interpreting sex differences in enamel hypoplasia in human and non-human primates: developmental, environmental and cultural considerations. Yearbook Phys Anthropol 42:73–126.

Guatelli-Steinberg D. 2003. Macorscopis and microscopic analyses of linear enamel hypoplasia in Plio- Pleistocene South African Hominins with respect to aspects of enamel development and morphology. Am J Phys Anthropol 120:309–22.

Haduch E. 2002. The human biology of the Neolithic and bronze age population of Poland. In: P Bennike, E Bodzsar and C Susanne,editors. Ecological aspects of past human settlements in Europe. Budapest:Eőtvős University Press. 143–56.

Henneberg RJ, Henneberg M. 1989. Dental caries and enamel hypoplasia in a rural population of the ancient Greek Colony of Metaponto, Italy. Am J Phys Anthropol 78:240.

Herring DA, Sauders SR, Katzenberg MA. 1998. Investigating the weaning process in past populations. Am J Phys Anthropol 105:425–39.

Hillson S. 2002. Dental Anthropology. Cambridge: Cambridge University Press.

Hillson S. 2008. Dental pathology. In: MA Katzenberg and SR Saunders, editors. Biological anthropology of the human skeleton.New Jersey: Wiley-Liss. 301–40.

Hillson S, Bond S. 1997. Relationship of enamel hypoplasia to the pattern of tooth crown growth: a discussion. Am J Phys Anthropol 104:89–103.

Hoyenga KB, Hoyenga KT. 1982. Gender and energy balance: sex different in adaptations for feast and famine. Physiol Behav 28:545–63.

Jackes M. 2009. Teeth and the past in Portugal: pathology and the Mesolithic-Neolithic transition. In: T Koppe, G Mayer and KW Alt, editors. Comparative dental morphology. Basel: Krager. 167–72.

Jankowska D. 1999. Remarks on the study of consumption in the communities of the late Band Pottery Culture (LPC) and the Corded Ware Culture inhabiting Polish territories (a comparative study). In: D Jankowska, M Krenz-Niedbała, J Piontek and J Wierzbicki, editors. Biological and cultural consequences of the transition to agriculture in Central Europe. Poznań: Wydawnictwo Naukowe UAM. 27–44.

Kardow S, Machnik J. 1997. Kultura Mierzanowicka. Chronologia, taksonomia i rozwój przestrzenny. Kraków: Wydawnictwo Oddziału PAN.

Katzenberg MA, Herring DD, Saunders SR. 1996. Weaning and infant mortality: evaluating the skeletal evidence. Yearbook Phys Anthropol 39:177–99.

Keenleyside A, Panayotova K. 2006. Cribra orbitalia and porotic hyperostosis in a Greek colonialpopulation (5th to 3rd centuries BC) from the Black Sea. Int J Osteoarchaeol 16: 373–8.4.

Kempisty A, Włodarczyk P. 1996. Chronologia absolutna cmentarzyska w Żernikach Górnych, woj. Kieleckie. In: A Kempisty and P Włodarczyk, editors. Concordia. Studia ofiarowane Jerzemu Okuliczowi-Kozarynowi w sześćdziesiątą piątą rocznicę urodzin. Warszawa: Wydawnictwa UW. 127–40.

Köhler K, Pálfi G, Molnár E, Zalai-Gaál I, Osztás A, Bánffy E, et al. 2012. A Late Neolithic case of Pott's disease from Hungary. Int J Osteoarchaeol doi:10.1002/oa.2254.

King T, Humphrey LT, Hillson S. 2005. Linear enamel hypoplasias as indicators of systemic physiological stress: evidence from two know age-at-death and sex populations from postmedieval London. Am J Phys Anthropol 128:547–59.

Krenz-Niedbała M. 1999. Morphological response to living conditions in the populations of Corded Ware Culture and Lengyel Culture. In: D Jankowska, M Krenz-Niedbała, J Piontek and J Wierzbicki, editors. Biological and cultural consequences of the transition to agriculture in Central Europe. Poznań: Wydawnictwo Naukowe UAM. 83–103.

Krenz-Niedbała M. 2000. Biologiczne i kulturowe skutki neolityzacji w populacjach ludzkich na ziemiach polskich. Poznań: Wydawnictwo Naukowe UAM.

Krenz-Niedbała M. 2001. Biological and cultural consequences of the transition to agriculture in human population on Polish territories. Variability and Evolution 9:89–99.

Krenz-Niedbała M, Kozłowski T. 2011. Comparing the chronological distribution of enamel hypoplasis in Rogowo, Poland (2nd century AD) using two methods of defect timing estimation. Int J Osteoarchaeol doi: 10.1002/oa.1262.

Kruk J. 1980. Gospodarka w Polsce Południowo-Wschodniej w V–III tysiącleciu p.n.e. Kraków: Wydawnictwo Oddziału PAN.

Kruk J, Milisauskas S. 1999. Rozkwit i upadek społeczeństw rolniczych Neolitu. Kraków: Instytut Archeologii i Etnologii PAN.

Kujanová M, Bigoni L, Velemińska J, Velemińsky P. 2008. Limb bones asymmetry and stress in medieval and recent populations of Central Europe. Int J Osteoarchaeol 18:476–91.

Larsen CS. 1995. Biological changes in human populations with agriculture. Annu Rev Anthropol 24:185–213.

Larsen CS. 2003. Bioarcheology.Interpreting behavior from the human skeleton. Cambridge: Cambridge University Press.

Liebe-Harkort C. 2012. Cribra orbitalia, sinusitis and linear enamel hypoplasia in Swedish Roman Iron Age adults and subadults. Int J Osteoarchaeol 22:387–97.

Limbo J. 2006. Dental enamel hypoplasia in the Pada cemetery (12th–13th cc.) population in north-east Estonia. P Anthropol 15:114–23.

Liversidge HM. 2000. Crown formation times of human permanent anterior teeth. Arch O Biol 45:713–21.

Marlowe FW. 2005. Hunter-gather and human evolution. Evol Anthropol 14:54–67.

May RL, Goodman AH, Meindl RS. 1993. Response of bone and enamel formation to nutritional supplementation and morbidity among malnourished Guatemalan children. Am J Phys Anthropol 92:37–51.

Molnar P, Ahlstrom TP, Leden I. 2011. Osteoarthritis and activity – an analysis of the relationship between eburnation, musculoskeletal stress markers (MSM) and age in two Neolithic hunter–gatherer populations from Gotland, Sweden. Int J Osteoarchaeol 21:283–91.

Piontek J. 1999. Body size and proportions in the Upper Paleolithic-Neolithic transition: evidence from Central Europe. In: D Jankowska, M Krenz-Niedbała, J Piontek and J Wierzbicki, editors. Biological and cultural consequences of the transition to agriculture in Central Europe. Poznań: Wydawnictwo Naukowe UAM. 61–84.

Piontek J, Kozłowski T. 2002. Frequency of cribra orbitalia in the subadult medieval population from Gruczno, Poland. Int J Osteoarchaeol 12:202–08.

Piontek J, Vancata V. 2002. Transition to agriculture in Europe: evolutionary trends in body size and body shape. In: P Bennike, E Bodzsar and C Susanne, editors. Ecological aspects of past human settlements in Europe. Budapest: Eőtvős University Press. 61–92.

Reid DJ, Dean MC. 2000. Brief communication: the timing of linear hypoplasias on human anterior teeth. Am J Phys Anthropol 113:135–39.

Reid DJ, Dean MC. 2006. Variation in human enamel formation times. J Hum Evol 50:329–46.

Ritzman TB, Baker BJ, Schwartz GT. 2008. A fine line: a comparison of methods for estimating ages of linear enamel hypoplasis formation. Am J Phys Anthropol 135:348–61.

Smith BH. 1984. Patterns of molar wear in hunter-gatherers and agriculturalists. Am J Phys Anthropol 63:39–56.

Suckling GW, Herbison GP, Brown RH. 1987. Etiological factors influencing the prevalence of developmental defects of dental enamel in nine-year-old New Zealand children participating in a health and development study. J Dent Res 66:1566–69.

Temple DH. 2010. Patterns of systematic stress during the agricultural transition in prehistoric Japan. Am J Phys Anthropol 142:112–24.

Tomczyk J, Sołtysiak A, Tomczyk-Gruca M. 2007. Temporal changes in frequency of enamel hypoplasia in the Middle Euphrates Valley (Syria). In: EB Bodzsár and A Zsákai, editors. Human diversity and biocultural researches. Budapest: Plantin-Publ. & Press. 87–97.

Tunia K. 1986. Z problematyki środowiskowych uwarunkowań gospodarki pasterskiej na terenie górskiej strefy polskich Karpat Zachodnich w czasach prahistorycznych. Acta Archaeol Carpathica 25:219–30.

Wierzbicki J. 1999. Characteristics of the cultural-chronological position of Neolithic burial grounds at Osłonki, Złota and ŻernikiGórne. In: D Jankowska, M Krenz-Niedbała, J Piontek and J Wierzbicki, editors. Biological and cultural consequences of the transition to agriculture in Central Europe.Poznań: Wydawnictwo Naukowe UAM. 7–25.

Wright LE. 1997. Intertooth patterns of hypoplasia expression: implications for childhood health in the Classic Maya Collapse. Am J Phys Anthropol 102:233–47.

Villalpando S. 2001. Feeding mode, infections, and anthropometric studies in early childhood. Pediatr 106:1282–83.

Zilberman U, Smith P, Piperno M, Condemi S. 2004. Evidence of amelogenesis imperfecta in an early African Homo erectus. J Hum Evol 46:647–53.