

Harris Lines in the Non-adult Great Moravian Population from Mikulčice – the Comparison of Inhabitants of the Castle and Sub-castle Area

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Harris lines (HL) have been recognised as indicators of health status since the 1930s (HARRIS 1931). Although a number of research projects have studied the causes of HL development, their aetiology remains unclear. In general, these transversal, sclerotised layers are considered to be a reaction to a pathological condition or some form of malnutrition. We evaluated HL in a group of 122 non-adult individuals from the Great Moravian power centre at Mikulčice. We monitored the incidence of these lines on the long bones of limbs- the humerus, femur and tibia. This study confirmed that the highest incidence of HL was on the distal section of the tibia. The lines most frequently formed in the period between the 1st and 3rd year of life. A relationship between the number of lines and social status of the given individual (localisation of the grave within the agglomeration, the character of the grave equipment) was not demonstrated.

Key words: Harris lines – Great Moravian population – non-adults – non-specific stress

1. Introduction

Harris lines (HL) are transversal, sclerotised layers within spongy bone tissue. They were first described by H.A. Harris who studied their incidence in the recent population and are thus named in his honour (HARRIS 1931). They develop in the region of the metaphysis of long bones and run perpendicular to the bone diaphysis, parallel to the epiphysis (HUMMERT/VAN GREVEN 1985). They either cross it partially or completely. Apart from long bones, they may also occur on flat bones, such as for example the scapula, near the *fossa articularis*, and the pelvis, near the *crista iliaca*. They have also been observed on short

bones, on the carpal and tarsal bones, where they develop around the bone centres (KÜHL 1980).

HL may be evaluated on longitudinal bone sections or on X-Ray images. The use of X-Rays, a non-invasive method, is preferred.

HL are a manifestation of a temporary or complete growth arrest during bone development and they develop as a result of discordance of the growth mechanism between cartilage cells and osteoblasts (VYHNÁNEK et al. 1986). Subsequent resumption of growth is necessary for the development of HL (STEINBOCK 1976).

HL manifest with various intensity. It is presumed that the intensity of HL manifestation reflects the severity of the stress suffered and its duration. Thus, intensity, or more exactly the density of the lines, is taken into consideration during their evaluation. Sometimes, though, these lines may show some variability in intensity in one or more of their regions (throughout their

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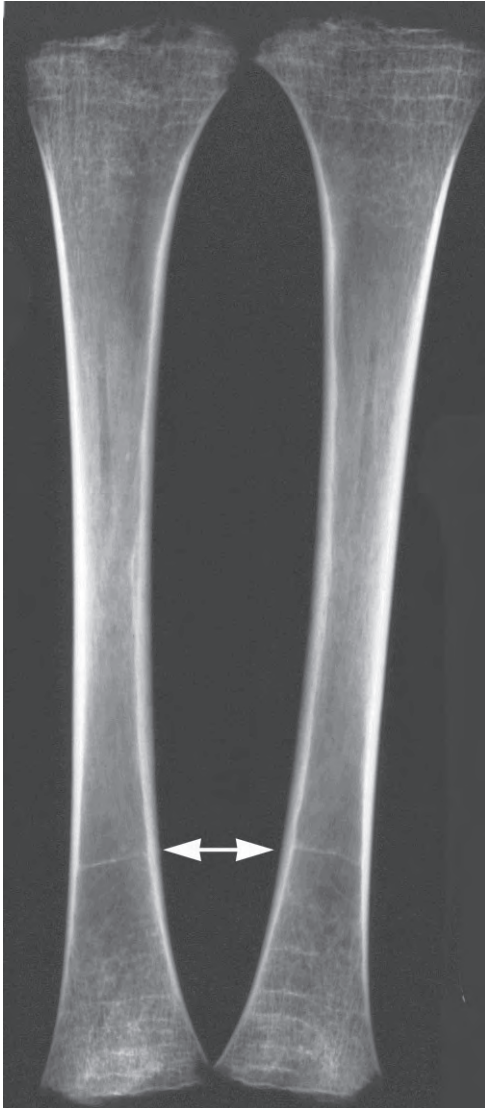


Figure 1. Harris lines on an X-Ray image of the tibia.

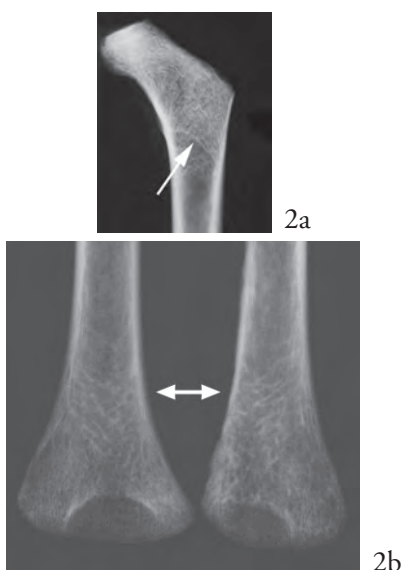


Figure 2a, 2b. Harris lines on an X-Ray image of the proximal femur (a) and the distal humerus (b).

course). As a rule, they are less intense near the marrow cavity (HUGES/HEYLINGS/POWER 1996).

The tibia is the most suitable bone for studying HL. HL occur more frequently in the distal sections of the tibia than in other bones. Also, thanks to the shape of the tibia, examination and analysis of these lines is easier, compared to the other long bones. Problematic areas are especially those with multiple epiphyses and apophyses, for example the proximal section of the femur or the distal part of the humerus. Here, the course of the lines may be tortuous and of varying intensity, which may complicate their analysis.

Although research of HL has been underway since the 1930s, their aetiology remains unclear. Many factors play a role in the development of HL (VYHNÁNEK/STLOUKAL 1991). Various forms of malnutrition, especially vitamin or protein deficiency, are quoted as the most frequent cause of their development (WOLBACH 1947; PARK/RICHTER 1953; DREIZEN/SPIRAKIS/STONE 1964). Other presumed causes may include acute diseases, especially childhood infectious diseases – measles, mumps (MARSHALL 1968; GINDHART 1969), various type of anaemia or heavy metal poisoning (CAFFEY 1931; WELLS 1967). Some authors also see a connection between the development of HL and psychological stress (SONNTAG/COMSTOCK 1938). This, though, is probably an attendant symptom of physical stress and exertion. As HL also develop in the prenatal and perinatal period, and diseases of the mother or her malnutrition may play a role in their development (HARRIS 1931; SONNTAG/COMSTOCK 1938). Development of these lines may also be due to neonatal shock at delivery (WELLS 1964, 1967) or to the so-called “weaning hypothesis”, i.e. the change in quality of nutrition when switching from breastfeeding to a normal diet (see enamel hypoplasia) (LEWIS/ROBERTS 1997).

Most studies focusing on the aetiology of HL were conducted on animals, where it is relatively easy to set and regulate the experimental conditions (PARK/RICHTER 1953; STEWART/PLAT 1957). This type of experiments mainly focuses on the monitoring of nutritional deficiencies or

of various forms of poisoning that either induce the development of HL or not. From an anthropological point of view, longitudinal studies conducted on living individuals of the current population are the most interesting sources of information regarding HL. Their contribution lies in the possibility of monitoring the gradual development and subsequent resorption of these lines in real time. Findings from such studies may then be applied to historical material (e.g. WELLS 1967). Unfortunately, today, such types of studies are no longer possible due to ethical and medical reasons.

A more or less solitary study of this type is the work of Patricia GINDHART from 1969. This is a longitudinal study involving more than 650 boys and girls, including medical records of diseases suffered and X-Ray images at relatively frequent intervals (every three months up to the age of one, then every six months up to the age of 12 and annually from the age of 12 to 14). Among others, this study showed that HL occur after suffering an illness in only 25% of cases. Thus, it was previously erroneously presumed that HL reflect all more serious diseases suffered.

Nonetheless, thanks to the presumed correlation between the number of HL and the health status of a population, it is possible to infer from their various incidence the different living conditions both among populations and among individuals within a single population. Most of the current studies involving past populations are based on this fact. They thus restrict themselves only to the monitoring of the number of HL, as any detailed study of the causes of HL development is not possible.

In the case of HL, we may also estimate the period of their formation. This is based on the understanding of the growth of long bones and on the position of the line within the bone (HUNT/HATCH 1983; BYERS 1991). Thus, it is possible to estimate the approximate age when the given individual experienced a certain stressful event.

The study of HL is naturally limited by several facts. As a consequence of the re-modelling of the

internal bone structure in later life and the associated resorption, the application of HL in the adult population is restricted. Just like the development of HL, bone re-modelling is individual. Sometimes, it is possible to observe a greater number of lines even in individuals of advanced age. The non-adult population is preferred, though, for the study of HL lines. Yet bias and distortion may occur even in such cases, as individuals who died at a young age may represent unusually weak and ill individuals.

Despite all these drawbacks, Harris lines, along with many other signs, remain one of the indicators of the health status of individuals from past populations.

2. Materials

The skeletal material comes from the Great Moravian power centre at Mikulčice, which dates to the 9th-10th century AD (POLÁČEK 2000). Several burial sites have been uncovered at this locality, usually in the vicinity of churches, both within the area of the castle and the sub-castle.

In our study, we used the skeletal remains of 73 individuals buried near the churches in the area of the castle itself – acropolis (Ist - Vth church, XIIth church) and 49 individuals from several burial sites located in the sub-castle area (VIth, IXth church, Klášteřisko and Kostelisko). This selection, along with the differentiation of individuals according to their grave equipment, enables the monitoring and comparison of the health status of individuals on the basis of their presumed social status, and thus their living conditions.

The skeletal material used for the study of Harris lines included 122 non-adult individuals of undetermined sex. The evaluation was conducted only in those individuals who had at least two long bones preserved – femur, tibia or humerus. We evaluated a total of 106 non-adult individuals with minimally one femur, 75 individuals with minimally one tibia and 94 individuals with minimally one humerus. For evaluation of side asymmetry associated with HL incidence,

Table 1. List of burial grounds studied.

Site	Burial-ground	Castle/Sub-castle	Publication	N of graves
I, II. church	I.	castle	Stloukal 1963	19
III. church (bazilica)	II.	castle	Stloukal 1967	45
IV. church	III.	castle	Stloukal 1969	5
V. church	V.	castle		1
XII. church		castle	Stloukal/Vyhnánek 1998	3
VI. church	IV.	sub-castle	Stloukal 1964	23
IX. church		sub-castle		4
Kostelisko		sub-castle	Velemínský et al. 2005	5
Klášteřiško		sub-castle	Stloukal/Hanáková 1985	17
Total				122

it was necessary to evaluate pairs of bones. Their numbers are summarised in Table 2.

3. Methods

As mentioned previously, this work was conducted on three types of long bones – the femur, tibia and humerus. Most studies use the long bones of the lower limb, where HL are clearly observed thanks to their more rapid growth (ELIOT/SOUTHER/PARK 1927; PARK 1964). This is especially true of the tibia (GINDHART 1969; HUMMERT/VAN GREVEN 1985; BUIKSTRA/UBERLAKER 1994), where the incidence of HL is greatest and the analysis of lines poses no problems. Rapid growth leads to greater distances between the developed lines, and thus facilitates their analysis (HUNT/HATCH 1981). Despite these findings, we additionally analysed HL on the femur and humerus for the purpose of comparison.

Table 2. Number of individuals studied by individual bones.

	N		
	Individuals	Bones	Pairs
Fe	106	181	75
Ti	75	123	48
Hu	94	155	61

The basic prerequisite for bone selection is their good preservation. In order to be able to use a bone, it is important that its compacta, and subsequently internal architecture, remain intact. In view of the aforementioned facts regarding bone re-modelling in later age and the subsequent resorption of lines, we worked with a non-adult population from birth until the age of 18.

It is known from many previous studies that the incidence of HL is symmetrical on both sides, and thus research is usually conducted only on one bone from a pair. In order to confirm this theory and to increase the reliability of the analysis of these lines, we tried to analyse the lines on both bones of a pair whenever the skeleton's state of preservation allowed (for the number of pairs see Table 2).

The selected bones were then X-rayed using the following parameters: focal length 110 cm, range approx. 50mA, approx. 1.25 mAs, time 0.03 s, approx. 46 kV. Each bone was X-rayed in two positions – antero-posterior and medio-lateral. This increases the precision of HL analysis and also reduces observer error (e.g. VYHNÁNEK/STLOUKAL 1988). Another possibility is to study HL on a cross-section of the bone, but this method is highly destructive.

The X-rays were then digitised using the Microtek (ScanMaker 64000XL) scanner and SilverFast 4 software. The analysis of the lines itself and the measurement of their distance from the ends of

epiphyses was conducted using the Sigma Scan Image Pro 6.0 software for image analysis.

During the analysis itself, we based our investigation on the work of GOODMAN and CLARK (1981). The lines had to be visible to the naked eye and had to occupy minimally one half of the width of the diaphysis. According to the length of the lines, we then divided them into three groups: lines that intersected the whole length of the diaphysis, lines with a length $\frac{1}{4}$ - $\frac{3}{4}$ of diaphysis width and lines that occupied less than $\frac{1}{4}$. We also differentiated the lines according to their intensity into weak and strong lines, and we used only the distinctive lines in our final evaluation.

Statistical evaluation of HL frequency of incidence was conducted using the STATISTICA 6.0 program and Excel 2003.

For greater measurement reliability, we analysed the lines of each bone three times. In the case of tibias, a fourth measurement was conducted with regard to inter-personal measurement error (intra- and inter-personal error was tested with the aid of the Friedman's ANOVA by ranks).

Another outcome of the study of HL was the estimation of the period of their formation. For our calculations, we used the methodology described in the work of S. BYERS (1991), which uses several basic dimensions. It has been created for four types of long bones – humerus, radius, femur and tibia.

For the adult population, we based our analysis on four basic dimensions – the total length of the bone, the distance between the distal metaphysis and the distal end of the bone, the distance between the proximal metaphysis and the proximal end of the bone and the distance of the line from the nearer end of the bone; whereby the first three dimensions aid in the calculation of diaphysis length. The method itself is thus based on the calculations of equations derived from the aforementioned dimensions.

For the non-adult population, we monitored only two basic dimensions – diaphysis length measured from the most proximal end to the most distal (T) and the distance between HL and the end of the diaphysis (proximal - P,

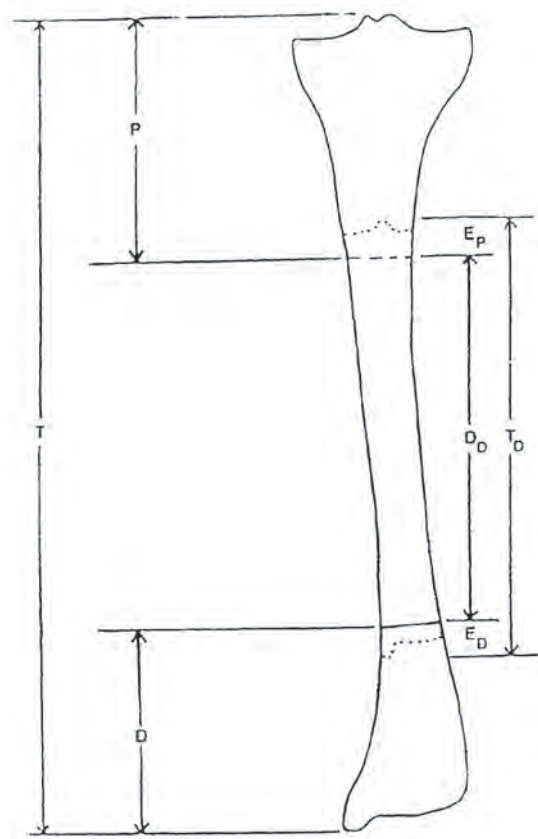


Figure 3. Drawing of bone with areas of measurement for determining age of HL formation (BYERS 1991).

distal - D), because the epiphyses are not as yet fully synostosed and thus the complicated identification of the metaphyseal border in order to calculate diaphysis length is not necessary. In view of this simplification, we used Byers equation for correction, in accordance with the work of VELEMÍNSKÝ et al. 2005 (Table 3).

The results acquired for both the adult and non-adult population represent the percentual ratio of bone length at the level of the observed HL. These must then be related to the ontogenetic model of long bones, i.e. the “actual” period of HL formation must be derived from this. For the non-adult population, we took as our basis the ontogenetic “tables” of the long bones of limbs drawn up directly for the Great Moravian population (STLOUKAL/HANÁKOVÁ 1978). In the adult population, it is more appropriate to use the conversion tables cited in Byers' work. We used the method of regression analysis for the statistical

Table 3. Modified Byers' method for non-adult populations according to VELEMÍNSKÝ et al. 2005.

Explanatory notes: Pct – percent of bone length, T – the total length, P/D – the distance from the transverse line to the closest end (proximal/distal)

		Byers 1991	Velemínský et al. 2005
Fe	prox.	$\text{Pct} = 1,12 (T - 3,33P) \times 100/T$	$\text{Pct} = (T - 3,33P)$
	dist.	$\text{Pct} = 1,12 (T - 1,43D) \times 100/T$	$\text{Pct} = (T - 1,43D)$
Ti	prox.	$\text{Pct} = 1,15 (T - 1,75P) \times 100/T$	$\text{Pct} = (T - 1,75P)$
	dist.	$\text{Pct} = 1,15 (T - 1,33D) \times 100/T$	$\text{Pct} = (T - 1,33D)$
Hu	prox.	$\text{Pct} = 1,09 (T - 1,23P) \times 100/T$	$\text{Pct} = (T - 1,23P)$
	dist.	$\text{Pct} = 1,09 (T - 5,26D) \times 100/T$	$\text{Pct} = (T - 5,26D)$

Table 4. Occurrence of HL on individual long bones of limbs.

		N of ind. with HL									
		N of ind.	N of HL	0		1		2 to 4		More than 5	
				N	%	N	%	N	%	N	%
Fe	prox .	106	11	100	94,3	2	1,9	4	3,8	-	-
	dist.		91	49	46,2	34	32,1	23	21,7	-	-
	total		102	47	44,3	32	30,2	26	24,5	1	0,9
Ti	prox .	75	87	33	44,0	15	20,0	27	36,0	-	-
	dist.		131	11	14,7	20	26,7	43	57,3	1	1,3
	total		218	8	10,7	11	14,7	40	53,3	16	21,3
Hu	prox .	94	4	91	96,8	2	2,1	1	1,1	-	-
	dist.		2	92	97,9	2	2,1	-	-	-	-
	total		6	89	94,7	4	4,3	1	1,1	-	-

evaluation of the irregular distribution of HL in relation to age.

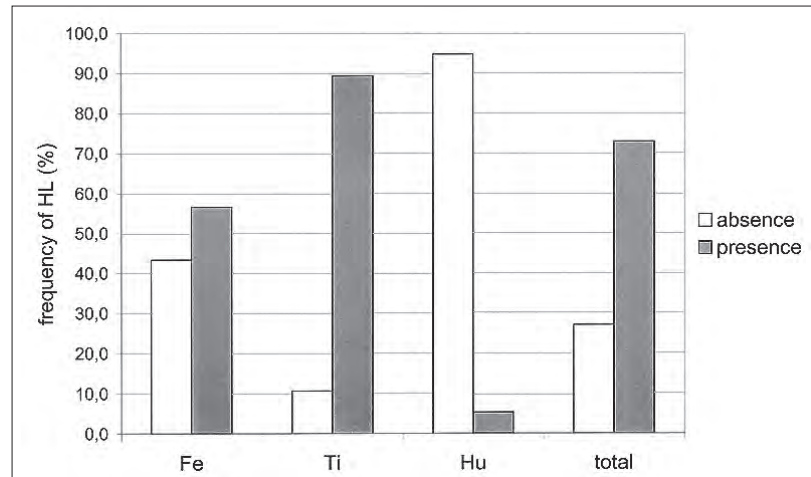
Based on the known findings regarding HL development, it may be presumed that the incidence of HL will be higher in individuals with worse living conditions. We thus studied the relationship between the living standard of individuals and the number of HL; or rather we compared the incidence of HL among individuals of various social status.

We inferred the social status of individuals from the character of their grave equipment (the archive of the Institute of Archaeology of the Czech Academy of Sciences, Brno). We also took into consideration the position of the given grave within the Mikulčice settlement agglomeration, that is whether the burial site was within the castle grounds themselves (Ist-Vth, and XIIth church) or

whether it was within the sub-castle area (VIth and IXth church, Klášteřisko and Kostelisko).

As to grave equipment, in view of the period from which the burial site originates, its exploitation in the determination of social status may be complicated by the onset of Christianisation of the population. At the time, pagan traditions were being abandoned, including the placing of gifts and offerings in the grave.

Nonetheless, we still presumed that individuals with poorer grave equipment or those buried in the sub-castle area or its surroundings probably enjoyed lower living standards, and thus we could expect a higher incidence of HL. On the contrary, we presumed that individuals with richer grave equipment or those buried within the castle itself would have a lower number of HL due to their better living conditions.



Graph 1. Occurrence of HL on individual long bones of limbs.

We divided the individuals according to their grave equipment using two methods. The first was based on the work of V. UNZEITIGOVÁ from 2000. This divides grave equipment into three groups:

1st group: jewellery, weapons, spurs, etc.

2nd group: objects of daily use (knives, vessels, etc.)

3rd group: no grave equipment

A much simpler division into two groups may be found in the works of STLOUKAL (1970) and VELEMÍNSKÝ (2000):

1st group: graves with swords, spurs, axes; graves with gold, silver or bronze objects.

2nd group: graves without equipment; graves with knives or other minor objects made of iron, ceramic or glass.

We used the χ^2 -test to verify our premises regarding both our comparison of the individuals from the castle and sub-castle, and the distribution of HL according to grave equipment.

4. Results

We observed a minimum of one line in more than 70% of individuals (89 from a total of 122 evaluated). No HL were observed in the remaining 33 individuals. The number of individuals with at least one line on individual bones is summarised in Table 4 and Graph 1.

As presumed, the highest incidence of HL was recorded on the tibia (nearly in 90% of cases). Minimally one line was observed on the femur in more than 56% of individuals, while the incidence

of HL on the humerus represented only 5% (6 lines in 4 individuals).

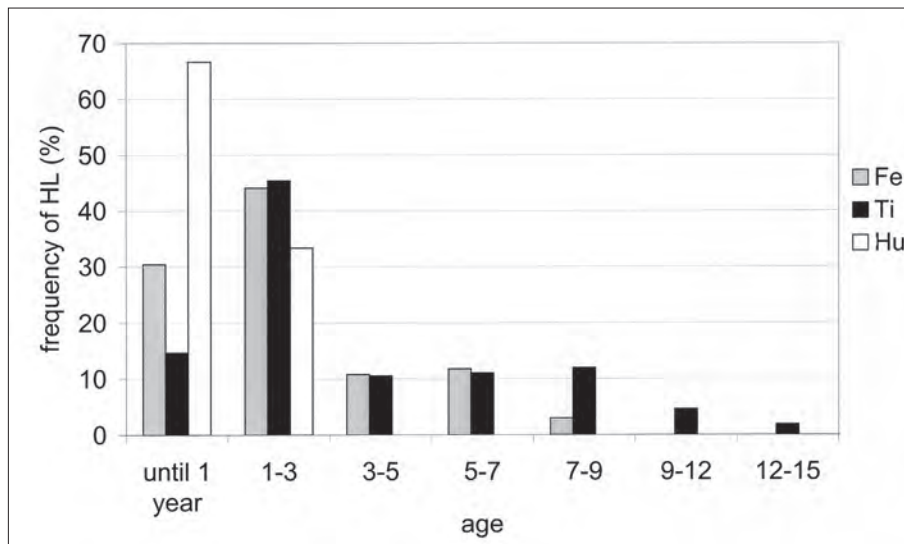
The high incidence of HL on the tibia is apparent even on the basis of the descriptive statistics summarised in table 5. This is especially clear if we focus on the median, which in the case of the tibia reaches a value of 3, in the case of the femur a value of 1 and is actually zero in the case of the humerus. The maximum recorded incidence of lines on a single bone – on its proximal or distal part – was eight, again in the case of the tibia.

Table 5. Descriptive statistics.

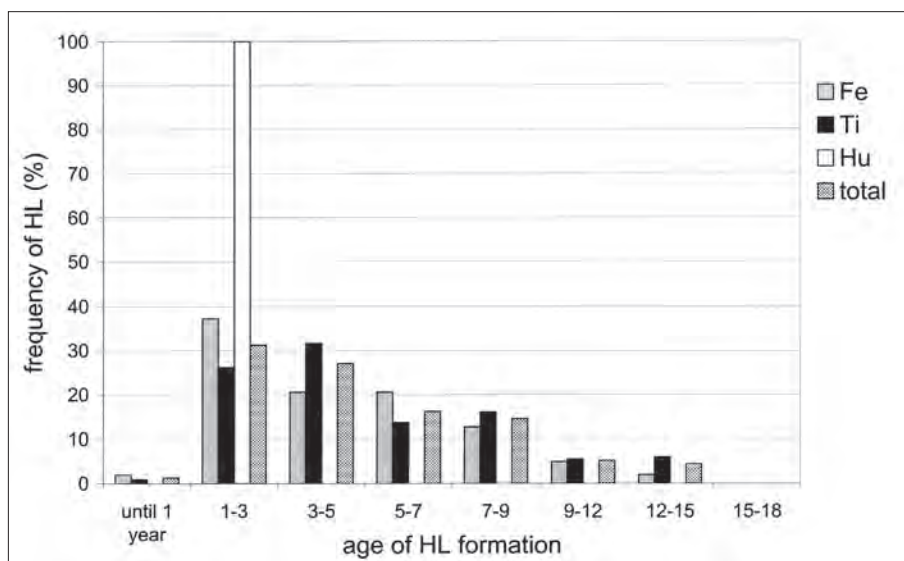
	Fe	Ti	Hu	Total
Mean	1,0	2,9	0,1	2,7
Standard error	0,1	0,2	0,0	0,2
Median	1	3	-	2
Mode	-	2	-	-
Standard Deviation	1,1	2,0	0,3	2,8
Maximum	6	8	2	13
N of HL	102	218	6	326
Valid N	106	75	94	122
HL/individual	0,96	2,91	0,06	2,67

As expected, with increasing age (age at death), we observed a decrease in the number of lines formed. The age distribution of HL is presented in Graph 2a.

As to the period of HL formation, the greatest number of lines, more than 40%, developed between the 1st and 3rd year of an individual's life. This applied to all the bones studied (Graph 2b).



Graph 2a. Frequency of HL in individual age groups.



Graph 2b. Distribution of HL by age of HL formation.

According to the results obtained, and on the basis of McNamara's test, we were also able to prove the hypothesis that HL occur symmetrically on the right and left side of the body. We monitored this side symmetry only in the femur and tibia, as the frequency of HL on the humerus was too low.

We evaluated the intra-observer error and inter-observer error of measurement in order to verify the method's objectivity. Based on the results of the Friedman's ANOVA by ranks, it is possible to consider the method of HL evaluation as objective and the deviations as statistically insignificant.

Table 6. Occurrence of HL according to grave equipment.

	Grave Equipment	N of ind. with HL	Total Individuals	% ind. with HL
Unzeitigová 2000	1 st group	13	18	72,2
	2 nd group	11	14	78,6
	3 rd group	65	90	72,2
Stloukal 1970	1 st group	17	23	73,9
	2 nd group	72	99	72,7

We used the χ^2 test to determine the distribution of HL in individuals buried within the castle or in the sub-castle area. As we could not reject the zero hypothesis regarding the uneven distribution of lines at neither the 0.05 nor the 0.01 level, our assumption that a lower incidence of HL reflects better living conditions in one of the studied populations was not confirmed (Graph 3a).

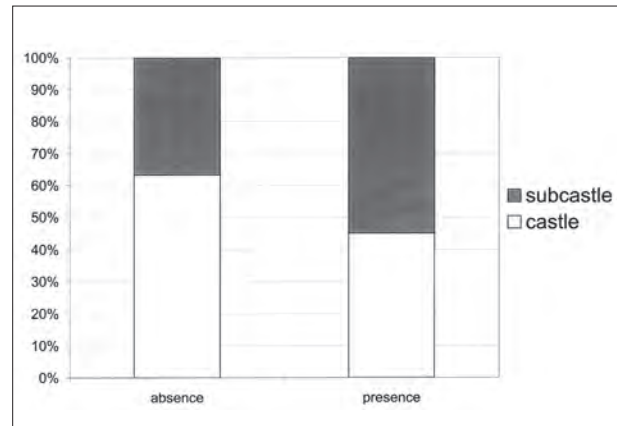
We also used the same statistical methods for evaluating the differences in the incidence of HL in individuals with different grave equipment. Similarly, in this case we did not record any significant differences between the individual categories. We rejected the zero hypothesis at a level of 0.9, which was not statistically significant (Graph 3b).

Table 6 includes more detailed information regarding the distribution of HL according to grave equipment.

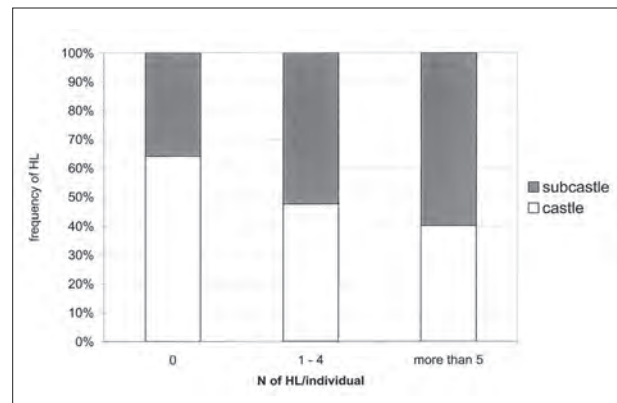
5. Discussion and conclusions

Harris lines were discovered on certain of the studied bones (femur, tibia, humerus) in more than 70% of non-adult individuals (89 of 122). As presumed, the highest incidence of HL was on the tibia (in nearly 90% of individuals). Occurrence on other bones was considerably less frequent, whereby HL were observed on the femur in 55% of cases and we detected only 6 lines (5%) in the case of the humerus.

These results thus confirm the conclusions of previous studies. It is well known that long bones are “most suitable” for the study of HL (BIUKSTRA/UBELAKER 1994), especially the bones of the lower limb – tibia and femur. Thanks to the more rapid growth of the bones of the lower limb, the distance between the lines increases and the HL are thus more amenable to observation and evaluation (ELLIOT/SOUTHER/PARK 1927; PARK 1964; HUNT/HATCH 1981). According to many previous studies, the highest incidence of HL has been recorded on the distal part of the tibia, followed by the proximal part of the tibia, the proximal part of the femur and the distal part of the radius.



Graph 3a. Distribution of HL according to the location of the burial ground – castle and sub-castle.



Graph 3b. Distribution of HL according to burial grounds, taking into account the number of HL per individual.

Thus, the tibia is the most suitable as well as the most frequently used bone for the study of HL, in view of the highest incidence of HL (GINDHART 1969; HUMMERT/VAN GREVEN 1985; VYHNÁNEK et al. 1986; HUGES/HEILINGS/POWER 1996; UBELAKER/PAP 1998).

The different incidence of lines on long bones has long been the subject of much deliberation. It may be presumed that these differences are due to the different sensitivity or resistance towards the same stress event (disease, malnutrition, etc.). In other words, individual bones have a varied sensitivity threshold to the effects of non-specific stress (HUMMERT/VAN GREVEN 1985). For example, for HL to develop on the femur, the effect of such stress must last for a longer period of time and must be more intense than in the case of the tibia.

The lower limbs are permanently exposed to the effects of great stress given their biomechanical function during locomotion and the impact of the weight of the trunk. From this aspect, the higher incidence of HL on the tibia is more difficult to interpret, as the section of the body exposed to the greatest stress is the hip (DYLEVSKÝ/DRUGA/MRÁZKOVÁ 2000). The development of a higher number of lines in the case of the tibia may be explained by an enhanced reaction of this bone even to short-term stress events, rather than by long-term constant stress. As mentioned above, the subsequent termination of the stress event is important for the development of HL. A greater number of short-term stress situations may thus consequently lead to the development of a greater number of lines.

Although in the past decades the study of Harris lines has received much attention, nearly no similarly dated and geographically close comparable material exists. Only a few studies exist, most of them involving the tibia. If we compare the incidence of HL on this bone, the results are quite similar. The first two studies relate to the same locality of Mikulčice. At the Mikulčice-Kostelisko (sub-castle) burial site, where both adults and children were evaluated, 86.7% of individuals were recorded to have HL (VELEMÍNSKÝ 2000). At the Josefov burial site, within the Mikulčice zone, over 80% of individuals had HL (STRÁNSKÁ et al. 2002). Other evaluated burial sites were located in Poland. At the burial site in Cedyňa, HL occurred in 86% of individuals (PIONTEK/JERSZYNSKA/NOWAK 2001), or rather 68% if only children were evaluated (JERSZYNSKA 1991). 81% of non-adult individuals with HL were recorded at burial sites near the St. Jacob and St. Christopher churches in Wrocław (GRONKIEWICZ et al. 2001). A similar incidence was recorded in differently dated and geographically located populations (e.g. MANZI et al. 1989). In view of the demonstrated and frequently studied resorption lines in later age due to bone re-modelling (GARN et al. 1968; MARSHALL 1968; GINDHART 1969), the number of individuals with HL in the older population

may be significantly lower. The decreased incidence of HL in a recent series of 160 adult men aged between 49 and 88 (average 67.3) who survived World War I is also apparently related to resorption. Lines were recorded on the tibias of only 22% of individuals (VYHNÁNEK/STLOUKAL 1991).

As mentioned before, lines are most frequently evaluated on the distal end of the tibia, usually only on one side of the body. The lines occur nearly regularly and symmetrically on both bones (VYHNÁNEK/STLOUKAL 1991; GROLLEAU-RAOUX et al. 1997). The presence of an asymmetrical line that developed in another period than the line on the contralateral tibia is rare (VELEMÍNSKÝ 2000; STRÁNSKÁ et al. 2002; ZÍTKOVÁ 2003).

We also focused on the period of line formation. As mentioned in the methodology, we used that according to BYERS (1991) for determining the age at which the lines formed. Byers created an ontogenetic model of the percentual growth increments of individual long bones in order to infer the period of HL formation. He based his model on four older ontogenetic studies (ANDERSON/GREEN 1948, MARESH 1955, ANDERSON/GREEN/MESSNER 1963, GINDHART 1973). The Byers model is designed separately for boys and girls. Optimally, ontogenetic conversion tables based on a geographically close and similarly dated population should be available for the subsequent evaluation of lines. From this aspect, the ideal study focuses on the growth of the long bones of limbs in the Great Moravian population (STLOUKAL/HANÁKOVÁ 1978). The goal of this study was to enable the estimation of biological age from the length of the long bones of limbs in children. Unfortunately, the sexual differences in ontogenesis are not taken into consideration here, as no reliable method for determining sex on the basis of children skeletons exists.

In all the bones studied, the greatest number of lines developed in the period between the first and third year of life. This period approximately corresponds to that, when the quality of the children's diet changes as a consequence of weaning. The high number of lines that develop during this

period is often explained by the so-called weaning hypothesis (e.g. LEWIS/ROBERTS 1997). Other studies, though, oppose this view. For example, the work of BLAKEY/LESLIE/REIDY from 1994, which studied the skeletal remains of African slaves from the 19th century. Although women were forced to wean their children as early as the 9th and 12th month, the greatest number of HL occurred in the period between the third and fourth year of life. The development of hypoplastic enamel defects is often associated with the weaning hypothesis (TREFNÝ/VELEMÍNSKÝ 2001).

Regardless of the cause of the development of these lines in a certain period, the results of our study are in accordance with the general premise that most lines develop by the 11th year of life (HATCH 1983). Certain studies, though, differ within this age range. While our work and several others (e.g. GINDHART 1969, GOODMAN/CLARK 1981, CARL-THIELE 1996, STRÁNSKÁ et al. 2002) equally cite the age between one and four years as the period of the highest incidence of HL, according to other studies (JERSZYŃSKA/NOWAK 1996; VELEMÍNSKÝ 2000; PIONTEK/JERSZYŃSKA/NOWAK 2001) these lines develop most often between the age of six and twelve. This may also be due to the different age characteristics of the given groups. Lines that developed earlier may be already resorbed in older individuals.

Finally, we focused on the relationship between the number of lines and the social status of the given individual. Social status was given by the localisation of the grave within the Mikulčice power centre (castle/sub-castle) and by the wealth of the grave equipment. We were unable to demonstrate such a relationship. The differences between the groups were not statistically significant. Nonetheless, if we look at Graph 3a and 3b, it is clear that the incidence of HL in individuals from the sub-castle area is “slightly” higher. This difference appears even more marked, if we divide the individuals according to the number of lines. The group of individuals without HL is more numerous in the castle, compared to individuals with more than five lines who predominate in the sub-castle

The differences are not statistically significant, though. The reason for this may be the uneven distribution of lines at the burial sites of the castle and sub-castle, or the lower number of studied individuals from the sub-castle. It also cannot be ruled out that the differences in living conditions of individuals buried at various burial sites in Mikulčice were not as great as we presumed.

Similarly, we reached statistically inconclusive results when evaluating the relationship between the incidence of HL and the character of grave equipment. In this case, the onset of Christianisation in Great Moravia may have played a significant role, as this ushered a departure from pagan traditions such as the placing of gifts and offerings into the grave (STLOUKAL/VYHNÁNEK 1976). This fact may have led to the lessening of differences between the individual groups of the population.

It cannot be ruled out that HL do not completely reflect the social status and living conditions of individuals from past populations. The average incidence of HL in non-adult individuals is more or less the same in various populations.

Finally, we may conclude that our study unambiguously confirmed the highest incidence of HL on the tibia, especially its distal end. The incidence of lines on the humerus was negligible. This fact may be associated with the biomechanical and locomotory stress suffered by bones. We may also consider the intensity of lines and its relationship with the degree of stress suffered. Here again, though, we encounter the greatest shortcomings of HL evaluation – resorption lines as a consequence of bone re-modelling. The study of this sign is thus more ideal in a non-adult population. If we do not discover lines on the skeleton of an adult human being, we cannot claim that none developed. Another problem involves the as yet ambiguous aetiology of HL development, as highlighted by Patricia GINDHART'S (1969) work that studied the relationship between HL and disease in children. According to the results of this work, only 25% of HL develop as the consequence of a concrete disease. It is thus difficult to evaluate HL- a manifestation of undergone non-specified stress- as an independent indicator of the health status of past

generations. Nonetheless, if we place HL in the context of other characteristics that reflect living conditions (e.g. cribra orbitalia or enamel hypoplasia, VELEMÍNSKÝ/DOBISÍKOVÁ 2000), then they may contribute towards the study of the lives of our ancestors.

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