Coll. Antropol. **32** (2008) 2: 543–550
Original scientific paper

Study of Harris Lines at the »Prat de la Riba« Necropolis – Third to Fifth Century AD

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A B S T R A C T

Harris lines (HL) are considered a nutritional or pathological stress factor in the study of past populations. This study attempts to contribute to the knowledge of the causal agents for HL in terms of assessing the health state of the population of Tarragona in the Roman period. The presence of HL has been analyzed in 614 long bones (214 humeri, 150 femurs and 250 tibias) from 243 skeletons. No HL have been observed in humeri. The frequencies of HL in femurs are higher than 27% and in tibias more than 48%. Although no significant differences in the presence of HL is found among age categories, it seems that the causal agents of these marks acted on individuals from the age of 5, an age from which the long bones of the lower extremities are more prone to producing HL. The hardened living conditions in the Dark Age of the Roman period in Spain between the third to fifth centuries A.D. may be the cause of the high prevalence of HL in this population.

Key words: *bone development, bone density, radiographic image, Roman Period, Spain*

Introduction

Harris lines, described by Harris in 1933 as evidence of previous arrest of growth due to illness, are bands of increased bone density transversal to the longitudinal axis of long bones and observable in radiographic images, although they have also been described in metacarpals and at the ends of the ribs[1]. They are also called transverse lines, lines of increased bone density, atrophied growth lines or arrested growth lines. Harris lines are the result of an increase in the deposition of bony tissue in a parallel deposit to the growing cartilage plate, caused by an imbalance in the level of chondrocytes and osteoblastic activity at a particular moment in the life of the individual when he or she was the victim of a temporary arrest in growth caused by the action of stress-causing factors[2] such as nutritional deficiencies and infectious diseases. The imbalance between the chondroblastic and osteoblastic functions ends up in an increase in calciferous deposition[3] which consists of a thinning of the epiphyseal plate due to a slowing in chondrogenesis with a greater resistance of the immature cartilage cells to the penetration of capillaries and osteoblasts. A primary osteoblastic layer is then deposited, replacing the mature cartilage cells under the metaphysial plate. When the stress-causing episode disappears, the osteoblasts of the primary layer create horizontally orientated trabeculi[1]. The essential condition for HL to be formed is the re-establishment of the normal state (disappearance of the stressful state), due to a re-establishment factor[4]. Therefore, it is possible to find individuals subject to chronic stress who do not show any HL[5].

The frequency of formation of HL correlates positively with the periods of greatest growth in childhood[1]. However, once they have formed, they undergo processes

Received for publication October 31, 2006

of bone resorption and remodelling throughout the life of the individual, so that the probability of observing them reduces as the age of the individual increases[6]. HL have been associated with episodes of general stress, malnutrition, diseases such as smallpox, whooping cough, measles, influenza, bronco-pneumonia, laryngitis, diabetes[5,7–8], and unusual causes, such as maternal state of health, emotional disturbances and weaning[5–6]. Other authors, however, have not found differences in the occurrence between well and poorly-nourished children, although they persist longer in children with nutritional deficiencies[6,9]. The fact that the conditioning factor for the formation of a line should be a temporary halt in growth has led some authors to interest themselves in the recovery of growth once re-established, by comparing it with the stature of the adult individual in order to assess whether or not the growth of the individual is normal. The scientific community has not reached consensus concerning the relationship between HL and growth. Therefore, while some authors have statistically correlated both facts (greater frequency of lines, greater final height of the individual)[10–11] others have obtained contrary results[6]. The possibility of being able to identify some of the stress-causing factors that produce HL means that, despite the passage of time, they continue to be a useful tool to obtain information about past populations.

This study attempts to contribute to the knowledge of the agents causing the formation of HL by analyzing a large population for which anthropological and pathological data are already known for comparison purposes. The chosen population is the »Prat de la Riba« Necropolis (Tarragona), a part of the great Paleo-Christian Necropolis of Tarragona, a main city of the Spanish Roman Province. The characteristics and size of this necropolis makes it an ideal sample to carry out anthropological and paleopathological studies as it is a necropolis with a large number of burials, in a good state of preservation and with known anthropological and pathological data, as well as being a historical one, so written sources can contribute to clarifying information about the population.

The results obtained may be statistically interpreted and generalized for the whole population of Tarraco, contributing to improve knowledge of the Roman society and the health status in the Hispania Citerior Area.

Material and Methods

In 1993, at the beginning of construction works on a private car park, the »Prat de la Riba« Necropolis was discovered on a site near the Paleo-Christian Necropolis in Tarragona. According to experts, it was the continuation of this necropolis. Within its total 1500m^2 area, 220 burials were discovered, from which 243 individuals were exhumed. Using Keay's typological system[12], up to 25 different types of amphora-like containers were described, establishing a dating for the necropolis of between the end of the third century A.D. and the end of the fifth century A.D.[13].

The pathology of skeletal material exhumed has been studied by Baxarias[14]. He determined the sex of 172 individuals using Ferembach and collaborators[15], and Schutkowsky[16] methods: 43.1% (74) were masculine and 56.9% (98) femenine. The femur and tibia are not conserved in the 172 individuals. The description of the sample according age categories and gender is in Table 1. The ages of skeletons were determined and represented (Figure 1) in intervals by Iscan and collaborators[17–18], Meindl and Lovejoy[19], Brooks & Suchey[20] methods. The highest inter-

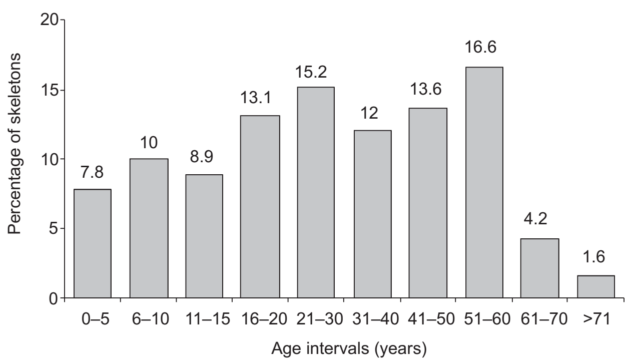

Fig. 1. Distribution of the population by percentage of age intervals.

TABLE 1
DESCRIPTION OF THE SAMPLE ACCORDING AGE AND GENDER CATEGORY

	Femur			Tibia		
	Female	Male	ND	Female	Male	ND
Infantile I	0	0	5	0	0	5
Infantile II	0	1	2	4	5	4
Youthful	5	3	1	13	5	1
Adult	9	3	0	14	9	0
Mature	10	8	0	14	13	0
Senile	1	0	0	2	3	0
N	25	15	8	47	35	10

Fem – female, Mal – male, ND – gender not determined, Infantile I – 0 to 6 years old, Infantile II – 7 to 12 years old, Youthful – 13 to 20 years old, Adult – 21 to 40 years old, Mature – 41 to 60 years old, Senile: greater than 60 years old vals of mortality are found between the ages of 21 and 30 (15%). The mortality rate of less than 5 years old represents 7.8% and, more specifically, 1.5% in the first year of life[14]. This mortality rate, in contrast, is considered low for ancient populations, where harsh conditions of life are reflected in high infant mortality. In this population, only 1.6% of the individuals lived longer than 60 years[14].

For the study of the HL a total of 614 long bones have been subjected to radiography with front and rear projection. The conditions in which this exposure was carried out were: source of 75mA, with penetration of the order of 45–60KV, moderate exposure time of less than 0.1 seconds at a distance of 1m[21]. The bones subject to radiography were the humeri, femurs and tibias of 145 individuals, out of a total of 243 individuals exhumed, whose long bones were preserved in good condition enough to carry out a radiography study of this kind. So, 214 humeri, 150 femurs and 250 tibias, from 115, 80 and 126 individuals respectively, were subjected to radiography. There is a good representation of the right and left sides of the different bones, so bilateral symmetry studies can be carried out (Table 2, Figure 2).

This study attempts to assess the prevalence of HL in one population. However, as Macchiarelli and collaborators[22] suggested, detection of HL in radiographic images is made more difficult by intra- and inter-observer variability. In order to narrow the concept definition of a HL and, therefore, identify it better in the bones subjected to radiography, an assessment of the presence of HL was carried out by four observers on radiographic images of ten bones in successive counts. The basic criterion of HL was distinct contrast of the bone substance extending across one-fourth or more of the width of the tibia diaphysis. The radiographic images chosen for carrying out this assessment had good sharp images, although, in order to reach an agreement on the difficult points, some of them had been chosen because they had multiple lines that were hard to assess. Each of the observers (all of them with different experience of identification) had to draw the Harris lines he or she observed on a sheet of transparent acetate superimposed on the radiography. The aim was to reach a consensus among the authors for defining HL in the radiographs with multiple HL, particularly the principal researcher responsible for assessing their presence, so that the subsequent count should be as objective as possible. The difficulty emerges in the case of sub-adults whose longitudinal bone growth – and therefore the distance between the lines – has not been finalized. Another factor lies on the fact that these bones have not undergone the bone remodelling and re-absorption processes with the same intensity as adult bones. These factors make counting difficult in such cases. Once the image considered as a HL had been agreed, the counting of the presence and absence of lines on each skeletal element went ahead. Statistical analysis was performed using the SPSS (Ver. 11.5) software.

Results and Discussion

Firstly, the results of the assessment of the presence of HL inter- and intra-observer are presented. Although there is variability in the initial assessment of the number of HL among the four observers, three of them show insignificant differences, despite the difference with the fourth observer is significant. For the three observers, over the course of the successive counts, inter-observer concordance increased and intra-observer variation reduced, so they came to coincide on the definition of what is considered as a HL. The assessments made by the fourth observer did not vary with the passage of time, as this person's counts were very strict from the start. So the directives agreed between the various observers were taken into account on the onset of the counting of HL in humeri, femurs and tibias.

No lines were observed in the proximal metaphysial region of radiographic images of humeri. Although HL had not been observed in humeri in this study, they have been mentioned by some authors[23–24].

The study of femurs was carried out on the radiographs of 80 individuals with a total of 150 femurs subjected to radiograph (76 from the right side and 74 from the left side). Of the 76 rights, 21 (27.63%) showed HL and, of the 74 lefts, there are 20 (27.0%) with lines (Table 2, Figure 3). Due to the fact that these percentages were very similar, it was thought necessary to assess whether the presence of HL was produced at the same time in the

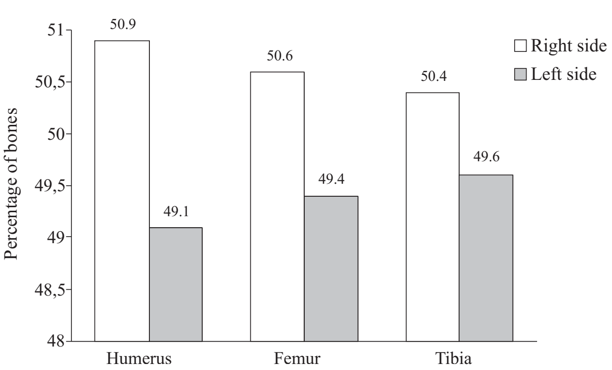

Fig. 2. Distribution of the sample according to type of bone and side.

TABLE 2
DESCRIPTION OF THE SAMPLE: PRESENCE AND ABSENCE OF HARRIS LINES ACCORDING TYPE OF BONE AND SIDE

	Side	HL presence	HL absence	Total
Humeri	R	0	109	109
	L	0	105	105
Femur	R	21	55	76
	L	20	54	74
Tibia	R	61	65	126
	L	61	63	124
Total		167	447	614

HL – Harris lines, R – right side, L – left side

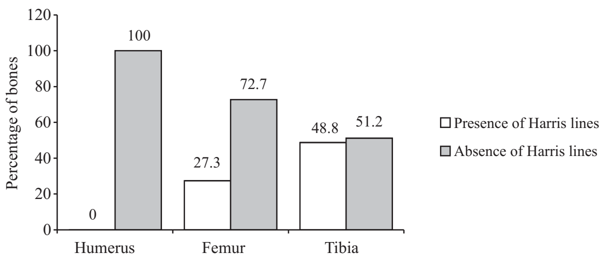

Fig. 3. Distribution of the sample according type of bone and presence/absence of Harris Lines.

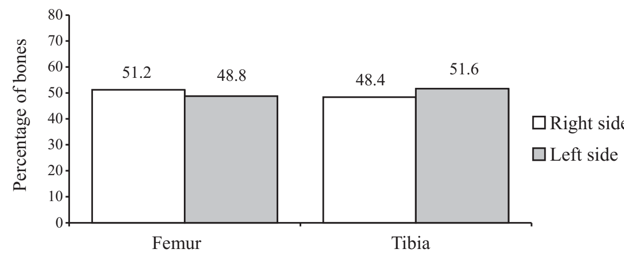

Fig. 4. Distribution of the sample with Harris Lines according to the bone type and its side.

two femurs of the same individual; that is, to assess their bilateral symmetry. Of 80 individuals studied, only 21 of these individuals have radiographs of the pair of femurs. And of these 21, only 18 individuals (85.7%) showed HL in the pair of femurs.

As for the 250 tibias subjected to radiography (126 from the right side and 124 from the left side) from 126 different individuals, 61 (48.41%) from the right side and 61 (49.2%) from the left side showed HL (Table 2, Figure 3). These results were lower than observed[25–26]. The presence of HL in both tibias was assessed. Of a total of 126 individuals, 58 (46%) showed HL in the pair of tibias. If the prevalence of bilateral symmetry is analyzed in the 61 individuals showing HL in the tibia (1 or 2 tibias affected), it was observed that 58 (93.5%) do so in both tibias at the same time. As with the case of the femur, the correspondence between the presences of lines on both sides is very high; only 6.5% (4 individuals) showed lines in only one of the two tibias.

Of the total population analyzed, 76 individuals showed bilateral symmetry in the HL in at least one of the parts which make up the lower extremity: tibia and/or femur. Of these 76 individuals, 12 (15.8%) showed HL both in the pair of femurs and in the pair of tibias, in which an analysis of femur-tibia correspondence can be carried out. However, all 4 bones (2 femurs and 2 tibias) were not preserved for all 76 individuals. They were found only for 29 individuals out of the total. So, the 12 individuals with all 4 bones with HL represented 41.38% of these individuals.

From all the above exposed, it is observed that the individuals showing HL in this population do not do so lightly, but do so considerable the majority symmetrically show HL in both segments of the lower extremity. But why do they appear only in the lower extremity and not in the upper one as well? Is the frequency the same in the different age categories? Do HL appear equally in men and in women? These are some of the questions arising from viewing these initial data. Mensforth[27] has already attempted to explain these issues based on changes during growth, »...The low prevalence of HL seen in the first year of life and during the adolescent growth spurt suggests genetically controlled chondroblastic stability during critical periods of growth and development. Chondroblastic stability would therefore appear to dominate the expression of growth arrest lines in the face of environmental insult...« Hughes and collaborators[6] also noted that the bones in the lower extremities grow more quickly because of the better circulation conditions, so that osteoblasts predominate in this area, facilitating the formation of the transverse lines in these bones if the conditions change.

TABLE 3
ASSOCIATION BETWEEN PRESENCE AND ABSENCE OF HARRIS LINES AND AGE CATEGORY

		Infantile	Youthful	Adult	p
General	No HL	9	9	39	
	Yes HL	13	14	33	0.326
Femur	No HL	4	9	33	
	Yes HL	5	2	7	0.046*
Tibia	Yes HL	8	10	37	
	No HL	13	13	30	0.316

Infantile – age category that include Infantile I (0 to 6 years old) and Infantile II (7 to 12 years old) categories, Youthful – age category (13 to 20 years old), Adult – age category that include adult category (21 to 40 years old), mature category (41 to 60 years old) and senile category: greater than 60 years old) categories, p – level of significance, No HL – absence of Harris lines, Yes HL – presence of Harris lines, * – significant (χ^2-test)

TABLE 4
ASSOCIATION BETWEEN PRESENCE7ABSENCE OF HARRIS LINES AND AGE CATEGORY (SUB-ADULT AND ADULT)

		Sub-adult	Adult	P
General	No HL	18	35	
	Yes HL	27	30	0.126
Femur	No HL	13	32	
	Yes HL	7	6	0.054
Tibia	No HL	18	33	
	Yes HL	26	27	0.0128

Sub-adult – age category that include Infantile I (0 to 6 years old), Infantile II (7 to 12 years old) and Youthful (13 to 20 years old) categories, Adult – age category that include Adult (21 to 40 years old), Mature (41 to 60 years old) and Senile (greater than 60 years old) categories, No HL – absence of Harris lines, Yes HL – presence of Harris lines

Starting from the idea that one bone can grow much more quickly than another; the former will be quicker to show a temporary arrest in growth caused by a disturbance, whatever this disturbance may be. Byers[23], in his work, evaluated the percentage of length of mature bone in the long bones (humerus, radius, femur and tibia) both for male and female sexes. In the tables, he established that the speed of growth of each bone can be indirectly associated. It is observed that in both, boys and girls, up to 4 years of age, the percentage of length of mature bone is greater in the long bones of the upper extremities (humerus and radius) compared to the lower extremities (femur and tibia). The rate of growth of the upper extremities is therefore greater compared to the other bones and at this stage they are more prone to the formation of HL. Between the ages of 5 and 7, the speed of growth of the femur increases, followed by the humerus and the radius, and it is from age 7 onwards that the speed of growth of the femur and tibia increases, taking from that age the lead in the formation of transverse lines. The lines are also prone to forming in the upper extremities, but less easily. If transverse lines have been formed at very early ages, these are subject to the processes of bone remodelling and reabsorption for a longer period than those formed in the lower extremities, which have been formed later.

If these data on the rate of growth are applied to data coming from the »Prat de la Riba« necropolis, it would explain the fact that HL are not found in the humerus, either because there has been remodelling or because the causal agent would have acted after the age of 4. The fact that no HL were found in humeri of any individual, that femurs showed a relatively high frequency of HL and that tibias showed them in greater numbers, indicates that the causal agent would most probably have had a greater effect after the age of 7 rather than the bones having been remodelled. It must be remembered that in no case does any HL appear in the humeri.

Therefore, the next step was to analyze the presence of HL according to age categories. The age categories are described (Table 1). Despite the fact that the group of children in the population was 50 sub-adults, not all of them had long bones to submit to radiography. At the same time, among the individuals with femurs submitted to radiography, only 5 individuals in infantile I category (0 to 6 years old) showed lines and 3 in infantile II category (7 to 12 years old). So, for statistical reasons, all the infantile categories (infantile I and II) have been grouped into a single category (infantile category). For the same reasons, the elderly individuals (senile category) (Table 1) – just one individual with HL in the femur – have been added to the adult category (greater than 21 years). Therefore, the statistical analysis has been carried out, in the first place, on three new age categories: infantile (less than 12 years), youthful (13 to 20 years) and adults (greater than 21 years) (Table 3), secondly comparing the entire sub-adult category (grouping infantile I, infantile II and youthful categories) with the adults (grouping adult, mature and senile categories) (Table 4) and thirdly comparing infantile individuals (infantile I and II categories) and the rest of the population (grouping youthful, adult mature and senile categories) (Table 5). These comparisons are made in order to see whether re-absorption of HL is observed towards the adult stage of development and when it begins. The comparison between the different categories has been carried out, both for the femur and the tibia, using the χ^2-test.

When the analysis is carried out with three age categories (Table 3), no significant differences are observed between the presence and absence of HL for tibias among the different ages. Changes are observed for the femur towards the adult stage, when the number of individuals with no lines increases. It must be taken into account that, in the case of the femur absence of HL in infantile group and presence of HL in youthful group, the sample is small. Because of this reason, the number of tibias and femurs has been grouped to see whether there are significant differences when considering the number of skeletal items from the lower extremity. Again, no significant differences were found.

Most authors agree that HL are subject to the remodelling and reabsorption processes with age, their prevalence has been analyzed in the youngest age group to assess when this process begins to be observed. For this reason, both the transverse lines cases in the femur and the tibia, a χ^2-test have been applied (Table 3). When a χ^2-test is applied grouping together infantile I, infantile II and youthful categories in sub-adult group and comparing them with the adult group (adult, mature and senile categories) (Table 4), no significant differences are observed for tibias or femurs or for the set of pieces from the lower extremity.

However, when the youthful category is grouped with the adult group (Table 5) and compared with infantile category, no significant differences are found in the case of the tibia, although they are found in the case of the femur (p=0.013). If the three studies by age group are considered together, it is observed that never the tibia shows

TABLE 5
ASSOCIATION BETWEEN PRESENCE/ABSENCE OF HARRIS LINES AND AGE CATEGORY (INFANTIL AND OTHER)

		Infantile	Others	P
General	No HL	9	48	
	Yes HL	13	47	0.416
Femur	No HL	4	42	
	Yes HL	5	9	0.013*
Tibia	No HL	8	47	
	Yes HL	13	43	0.244

Infantile – age category that include Infantile I (0 to 6 years old) and Infantile II (7 to 12 years old) categories, Other – age category that include Youthful (13 to 20 years old), Adult (21 to 40 years old), Mature (41 to 60 years old) and Senile (greater than 60 years old) categories, No HL – absence of Harris lines, Yes HL – presence of Harris lines, * – significant (χ^2-test)

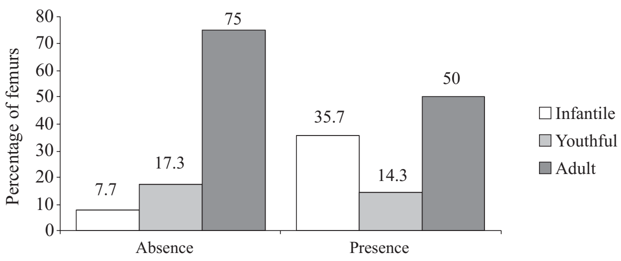

Fig. 5. Presence/Absence of Harris lines in infantile, youthful and adult age categories.

significant differences. In the case of the femur, significant differences are found when comparing the three age groups (p=0.046) (Table 3, Figure 5). When infantile and youthful categories are grouped together (Table 4) p= 0.054, the results are very closed to the significance level; and the differences are again significant when infantile category is compared with all the other categories (p= 0.013) (Table 5). This reflects the fact that the agent causing the formation of HL probably acted when the speed of growth of the femur was greater than that of the tibia, so that lines were produced and also reabsorbed in greater quantities than in the tibia.

Then, it seems that the process of remodelling HL does not begin in adolescence (as might be reflected in differences between sub-adults and adults) but occurs before it, as it would be reflected by the differences observed in femurs. The average age of the infantile group studied through the femur is 5.89, while the average age of the infants studied through the tibia is 8.05. This may reflect the fact that the agent causing the genesis of the HL has appeared at around the age of 5 and, therefore, the tibia has not had so long for the bone to remodel, whereas the femur has.

When a study is carried out to analyze differences in the presence of HL according to the gender of individuals (Table 6), it is observed that, in the light of values, both for the femur (p=0.842) and for the tibia (p=0.700), there is no significant statistical difference. This is an interesting result as some authors have found a relationship between the presence of transverse lines and the sex of the individuals[3,28,29]. Some studies reflect greater prevalence in males skeletons[3,29] and others in females skeletons[28]. This is not the case with the individuals from »Prat de la Riba«, where the causal agent of the HL would have acted in a similar way on both sexes in the population. Trace element analyses have been carried out to value the feeding and the health of the population of Tarragona along the Romanization period[30–33]. Differences in the feeding and health among the age sets and among the sexes, except among the several social classes, have not been found. So it is probable that the remodelling process does not differ according to sex and age.

Finally, in individuals from the »Prat de la Riba« necropolis, the prevalence of HL is high (27.63% in right femurs and 27% in left; 48.51% in right tibias and 49.2% in left), much more frequent in femurs of children and without differences between genders. This indicates a causal agent acting in infancy and equally in boys as in girls. But the issue of what this causal agent is remains open. At the beginning of the study, different possible causal agents mentioned in the literature were put forward. It should be added that some authors also mention weaning as a possible causal agent for the formation of HL as they consider that the breaking of this emotional relation between mother and child causes a stressful situation that could be reflected in different skeletal indicators. However, it should not be forgotten that this necropolis is dated between the third and fifth centuries AD. The crisis of Roman authority in Spain emerged during the third century AD, leading to a series of events which involved a radical change in the life of people in the Roman Empire. The crisis included a deep-seated political and economic crisis, with successive revolts grouped together in a dark age known in Spain as the period of Late Antiquity. The vitality of Tarraco (present-day Tarragona) kept with plenitude until middle III d.C. Roundabout this stage, the beginning of a process of progressive recession, in the demographic order as well as in the urbanize one[34] started as a consequence of a general crisis and the first invasion wave of Germanic people. It was a period when conditions of life toughened, as the prevalence of arthritis (24.4%) in a young population due to hard daily labour activity[14] reflects. Health conditions were also harsh, the feeding of the children was based on cereals and pulses, as shown by the studies of diet[35,36]. It was not a period of food shortage but a period of little variation and lack of animal origin proteins, very important during childhood growth stages and therefore important in the formation of the bone. This little variation would originate the HL in the moment of formation of the bone which will observe in the adult age. In fact, a situation of environmental and nutritional strong pressure could have affected the growth of infants. These results are similar to the ones observed in the mediaeval population in contemporary Central Europe[26]. The living conditions, as the authors quoted, would also have been the stimulating factor of the formation of the Harris lines.

Conclusions

»Prat de la Riba« population reflected the period of its era, a bad time in history, when the conditions of life were harsh, as denoted by the high prevalence of arthri-

TABLE 6
ASSOCIATION BETWEEN PRESENCE/ABSENCE OF HARRIS LINES IN FEMUR AND TIBIA, AND GENDER

		Female skeletons	Male skeletons	P
Femur	No HL	25	16	
	Yes HL	6	5	0.842
Tibia	No HL	28	23	
	Yes HL	29	22	0.700

No HL – absence of Harris lines, Yes HL – presence of Harris lines tis in a population that was not old, and where arthritis must be associated with hard work. At the same time, lack of a varied diet, along with the scarcity of meat products and the fact that vegetables would have played an important role have been extracted from the pathological and nutritional studies. This could also be reflected in the high prevalence of the presence of HL. The complete absence of HL in humeri, the maximum in tibias and the correlations found with the different age groups leads us to believe that the causal agent to which this population was subjected occurred before the age of 7. From Byers' (1991) growth tables and the average age of the infants analyzed, we can be more specific and state that the probable age for its beginning is around 5 and that it acted both equally on boys and girls. But what happened at around that age to cause a temporary arrest in the growth of individuals? Could it be that the cause was a largely vegetarian diet and therefore a deficiency in components of animal origin? Or could it be that a poor diet led to a worsening of the childhood illnesses normal at that age? It must be remembered that nutrition and disease are closely linked and it must therefore not be discarded that both together might be the possible cause.

Acknowledgements

This project has been carried out with the help of the Archaeological Museum of Tarragona. To thank Dr. Vila for the radiographic image interpretation, the collaboration of Mr.Vilaseca, and Dr. Baxarias and Dr. Campillo.This study was supported by the grant Fundació Caixa Sabadell, 2006.

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STUDIJA HARRISOVIH LINIJA NA NEKROPOLI PRAT DE LA RIBA (3.–5. ST. N. E.)

S A Ž E T A K

Harrisove linije (HL) se smatraju indikatorima stresa u studijama povijesnih populacija. Ova studija pokušava doprinijeti znanju o uzročnicima Harrisovih linija u smislu procjenjivanja zdravstvenog stanja populacije Tarragone u rimskom razdoblju. Prisutnost Harrisovih linija analizirana je na sveukupno 614 dugih kosti (214 kosti nadlaktice (humerus), 150 bedrenih kosti (femur) i 250 goljeničnih kosti (tibia) 243 kostura. Iako nije pronađena niti jedna značajna razlika u prisutnosti Harrisovih linija između dobnih skupina, izgleda da su uzročnici ovih oznaka djelovali na pojedince starije od 5. godine, što predstavlja godine od kojih su duge kosti i donji ekstremiteti skloniji nastanku HL. Teški životni uvjeti u mračnom dobu rimskog svijeta između 3. i 5. stoljeća n. e. mogu biti uzrok većem postotku učestalosti Harrisovih linija kod ove populacije.