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First Metatarsal Bones as Substitutes for Tibias in Harris Lines Studies on Past Populations

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Abstract: The first metatarsal bones (FMBs) are often better preserved than tibias in archeological samples. The aim of this study was to test the possibility of performing Harris lines studies on FMBs as stress markers instead of tibias. The Harris lines in 264 FMBs from a historic French burial site dating back to two burial periods were studied and compared with the Harris lines in FMBs from 4 historical and 2 Neolithic sites. The Harris lines in 57 tibias and FMBs were compared.

The intra-observer, inter-observer, side, and age-at-death variations were not found to be significant. The total prevalence of Harris lines was lower in the 16th-17th century sample than in the 11th-13th century sample, but no significant diachronic variations were observed between male and female samples. The Harris lines in the tibias and FMBs were not significantly correlated. Comparisons on the prevalence of the Harris lines showed the existence of significant differences between several samples, in keeping with the archeological data. In conclusion, the Harris lines in the first metatarsal bones studied showed significant intra- and inter-population variations. Further investigations are now required, however, to precisely access the value of using first metatarsals instead of tibias for Harris lines studies in bioarcheology or perhaps acknowledge that Harris lines have minimal scientific use as stress markers, except in unusual situations.

Key Words: Harris lines, first metatarsal bone, tibia, bioarcheology, prehistory, history, stress markers.

1. INTRODUCTION

The bioarcheological studies are now incorporated to multidisciplinary analysis of archeological sites. Skeletal remains of past populations are a major source of information on biocultural behaviors and adaptations. Environmental pressure, sociocultural situations and individual resistance determine the level of biological stress. Consequently, numerous analyses are focused on osseous and dental stress markers, mainly represented by skeletal growth disruptions, to determinate the importance of stress in past populations. For instance, enamel defects are considered as contributive markers of poor living conditions during childhood. Several skeletal indicators of stress need to be used to obtain a comprehensive knowledge of the level of stress in an archeological site.

Other stress markers frequently used are Harris lines that are radiographic diaphyseal transverse lines of increased density in long bones. Relationships between Harris lines and various stresses, i.e. acute illnesses [1], dietary deficiencies [2-5], traumatisms, and intoxications [6] have been described in modern populations. The distributions of Harris lines in the tibia and femur are often used in bioarchaeological studies as indicators of episodic nonspecific general stress during growth [7-11]. Actually, the interest of Harris lines as useful indicators of stress episodes is disputed [12, 13]. The correlation between the number of Harris lines in the long bones as tibias and the known stresses of an individual seems low [14]. Harris lines may appear in healthy children, and adults known as having severe stress during infancy may display no lines. Harris lines are considered, by some authors, as physiological phenomena during the growth of long bones that can only be accentuated by various exogenous and endogenous disorders [12]. In summary, each stress can cause the formation of one Harris line but one Harris line is not the true witness of each stress [14]. Moreover, the correlation of other stress markers, such as enamel hypoplasia, is also disputed [8, 12].

Harris lines are mainly studied in the tibia but important methodological difficulties have been noticed. Their scorings have high levels of intra-observer and interobserver variations [15]. There are differences between statistical methods used by the bioacheologists to compare the samples. Tibias are often fragmented in archeological samples and samples are often small. The tibias have two metaphysis, and the Harris lines are not always symmetrical in each side of the middle of the shaft. Bone remodeling in elderly subjects can explain the disappearance of the medullary bone that contains Harris lines in the middle of the shaft.

The main question is to determine if Harris lines cannot be used as stress markers or if using other bones that tibia or femur for Harris lines studies can provide best results.

For this study, a robust bone with preservation levels higher than those of tibias was needed because the samples must be sufficiently large for statistical analysis. Although Harris

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lines have previously been observed in first metatarsal bones, no study has been conducted to determine their validity as stress markers [14, 16]. These short but anatomically long bones are often better preserved than the tibias in archeological samples. The diaphyseal cavity is also smaller. Another interesting feature of the first metatarsal bone is that it has only a proximal metaphysis where most of the growth occurs even if a small part of the elongation of the shaft does occur at the distal extremity [17].

Fig. (1). First metatarsal bone with several Harris lines.

The purposes of this study were (i) to analyze the variability of Harris lines in first metatarsal bones in a larger sample with age at death and sex determination; (ii) to compare Harris lines in the first metatarsal bones and tibias; (iii) to assess the interest of Harris lines in the first metatarsal bones as an indicator of stress episodes.

2. METHODS

2.1. Samples and X-Raying

The main sample of this study included skeletons excavated from the graveyard at the Notre-Dame-du-Bourg cathedral in Digne, Alpes-de-Hautes-Provence department, France. The burial site was used for the inhabitants of the city from the 4^{th} to the 17^{th} century. Based on archeological data five different chronological periods have been identified and each grave was dated to an interval spanning a few centuries. The overall study sample included 297 first metatarsal bones and 57 tibias from skeletons of both sexes buried during two archeological periods, i.e., 11^{th} to 13^{th} century and 16^{th} to 17^{th} century.

Theses two samples from periods separated by about two centuries were chosen to allow analysis of diachronic variations and the impact of lifestyle changes. The first period was prior to the Great Plague that occurred in the 14^{th} and 15^{th} centuries and decimated the European population. The second period corresponds to the phase of demographic renewal in city of Digne.

Remains were grouped according to sex and age at death. Sex determination was made using the Bruzek method [18]. Two age-at-death groups were selected, i.e., under 30 years and over 50 years. Age under 30 years was determined based on the following criteria: absence of synostosis of skull sutures, molars either erupting or in place and showing no sign of wear and/or not fused iliac crests. Age over 50 years was determined based on the Lovejoy method as modified by Schmitt and Broaqua [19].

In addition the data were compared to several archeological samples from Southeastern France, for which data concerning socio-economic levels are available.

Two Neolithic sites, Le Capitaine and Les Boileau, provided 61 and 26 first metatarsal bones. The archeological data suggest that in Le Capitaine the population had better living conditions than in Les Boileau [20].

The Harris lines were also studied in four other samples from medieval burial sites with differences in socioeconomic contexts. Saint-Victor (5^{th}-6^{th} centuries) was the main burial site of the rich city of Marseille (75 FMBs) [21]. Beaulieu (5^{th}-6^{th} centuries) was a small and poor harbor town in French Riviera (56 FMBs).Ganagobie (11^{th}-13^{th} centuries) was a rich monastery in Provence where the nobility and monks were buried (56 FMBs) and La Gayole (11^{th}-12^{th} centuries) is a tiny, poor village in Provence (26 FMBs) [22].

For radiography, each first metatarsal bone was placed in a standardized position so that the lateral side of the diaphysis was in contact with the table. Radiographic constants were 45 kV, 5 mAs, using plain film at a cone distance of one meter to minimize distortion.

2.2. Interpreting the X-Rays

The radiographs were placed on a light box and visually examined at a distance of 40 centimeters. Harris lines were defined as any narrow and dense lines extending across one-fourth or more of the metatarsal shaft.

Statistical analysis was performed using a nonparametric test (Spearman's correlation test) and Chi-square, evaluated at the conventional level of alpha = 0.05.

3. RESULTS

3.1. Preliminary Study

The intra-observer (90 FMB) and inter-observer (77 FMB) variation were not significant (p: 0.09 and p: 0.406).

The comparison of the number of Harris lines on both side in 100 couples was not significant (p: 0.87) with a high correlation (r: 0.72). Age-at-death (i.e., <30 years old versus > 50 years old) variations were not significant (p: 0.63).

The sexual variations were only significant for the 16^{th} to 17^{th} century period (p: 0.042) with more numerous Harris lines in the first metatarsal bones of the male sample (Table **1**).

3.2. Diachronic Variation in the Notre-Dame-du-Bourg Population

The comparison of the 11^{th} to 13^{th} centuries sample to the 16^{th} to 17^{th} centuries sample gave discordant results depending of the statistical method used (Fig. **2**, Tables **2** and **3**).

The mean number of Harris lines was greater in the 11^{th} to 13^{th} centuries sample than in the 16^{th} to 17^{th} sample (p: 0.05), and the prevalence of first metatarsal bones without

Harris lines (that can be considered as testifying of a regular growth) was lower in the oldest sample (p: 0.023).

Table 1. Comparison of the Mean Number and Standard Deviation of Harris Lines in the First Metatarsal Bones Observed in Males and Females in the 11th to 13th Centuries Sample and in the 16th to 17th Centuries Sample from the French Historical Burial Site Notre-Dame-du-Bourg

	11th-13th		16th - 17th	
	Males	**Females**	**Males**	**Females**
N	32	49	26	43
Mean	4.098	3.816	3.462	2.767
SD	2.190	2.315	1.860	2.021

However, there was no statistical differences when the diachronic variation between the males samples of the two periods were tested, nor between the female samples but there is a high variability.

Table 2. Comparison of the Mean Number of Harris Lines in the First Metatarsal Bones Observed in the 11th to 13th Centuries Sample and in the 16th to 17th Centuries Sample from the French Historical Burial Site Notre-Dame-du-Bourg

	11th-13th	16th - 17th
N	95	125
Mean	4.116	3.92
SD	2.601	2.412

Table 3. Prevalence of First Metatarsal Bones Without Harris Lines Observed in the 11th to 13th Centuries Sample and in the 16th to 17th Centuries Sample from the French Historical Burial Site Notre-Dame-du-Bourg

	11th-13th	16th - 17th
With HL	106	149
Without any HL	4	19
%	3.6	11.6

3.3. Correlation of Harris Lines in the Tibia and First Metatarsal Bone

The correlation coefficient between the Harris lines observed in the first metatarsal bones and in the tibias of 57 skeletons was very low (r: 0.021, p= 0.440) (Fig. **3**). The mean number of Harris lines in the first metatarsal bones was greater that in the tibias but the high standard deviations may explain the lack of correlation (Table **4**).

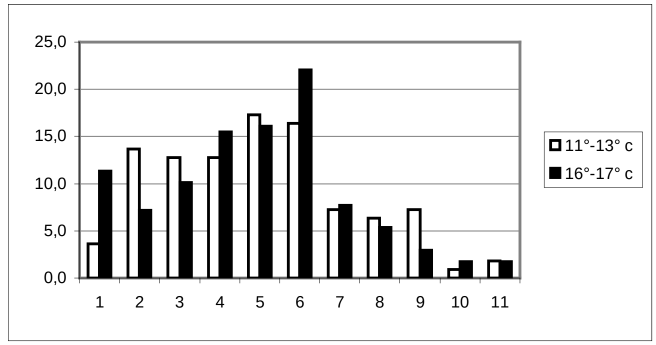

Fig. (2). Distribution of Harris lines in the first metatarsal bones observed in the 11th to 13th centuries sample and the 16th to 17th centuries sample from the French historical burial site Notre-Dame-du-Bourg.

The prevalence of tibias and first metatarsal bones without Harris lines was not statistically significant (14/57:24.5% versus 8/57: 14%; p: 0.23).

Table 4. Comparison of the Mean Number of Harris Lines Observed in 57 First Metatarsal Bones and Tibias from the French Historical Burial Site Notre-Dame-du-Bourg

	FMB	Tibia
N	57	57
Mean	3.79	1.719
S.D.	2.808	1.719

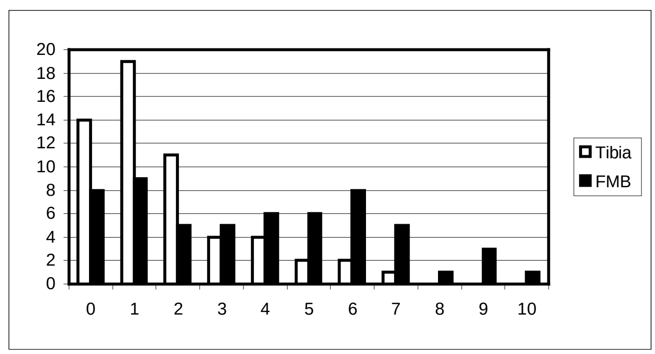

Fig. (3). Distribution of Harris lines observed in 57 first metatarsal bones and tibias from the French historical burial site Notre-Dame-du-Bourg.

3.4. Comparison of Two Neolithic and Four Historical Samples

There were no statistical differences between the samples (Spearman-'s rank correlation test) or when comparing the first metatarsal bones without Harris lines (Chi-square with Yates correction) apart from Notre-Dame-du-Bourg samples.

Associations were present but not statistically significant between a high socio-economical level (as suggested by archeological data) and a higher percentage of first metatarsal bones without Harris lines. For instance, the prevalence of first metatarsal bones without Harris lines is higher in the Neolithic site Le Capitaine than in Les Boileau. Samples from the two historical sites than are considered to have the best socioeconomic levels, (i.e. Saint-Victor de Marseille and Ganagobie, [22]) had the higher percentage of first metatarsal bones without Harris lines (Table **5**).

The small size of several samples may explain the lack of statistical differences.

Table 5. Percentages of First Metatarsal Bones Without Harris Lines in Several Neolithic and Historical French Burial Sites. Neolithic Sites

	Neolithic		Historical					
	A	B	C	D	E	F	G	H
N	26	61	75	56	20	26	110	164
%	3,8	19,7	22,7	10,7	10	23,1	3,6	11,6

(A) Les Boileau, (B) Le Capitaine; Historical sites (C) St Victor (5^{th}-6^{th} c.) (D) Beaulieu (5^{th}-6^{th} c.), (E) Ganagobie (11^{th}-13^{th} c.), (F) La Gayole (11^{th}-13^{th} c.), (G) Notre-Dame du Bourg 11^{th}-13^{th} c., (H) Notre-Dame du Bourg 16^{th}-17^{th} c.

4. DISCUSSION

To increase our knowledge of biological stresses in past populations, we need improved methods and stronger analysis that will lead to better theories. Since Harris line studies of the tibia are disputed and statistical analyses are limited, owing to a tendency toward fragmented tibia bones, first metatarsals provide an adequate substitute, given their greater frequency and lessened fragmentation in archeological samples. This most likely is due to the single metaphysis and better preservation of the diaphyseal medullary bone in first metatarsals, which can reduce a disappearance of Harris lines. Lack of correlation for Harris lines across tibias and first metatarsals, however, will necessitate the generation of additional baseline data for reliable analysis, and already existent data on tibias will require careful assessment for their individualized validity, based on particular situations, populations and time periods.

Harris lines in the first metatarsal bones exhibit intra- and inter-population variations, but contrasting results are obtained using several statistical methods for comparing the different archeological samples.

This study have demonstrated that using the first metatarsal bones is interesting to study Harris lines, to get numerous data, and to avoid or minimize the error for counting as observed with the tibias. Further investigations are required to precisely determine their possible association with nonspecific stress in larger and well-documented archeological and modern samples. The statistical methods that are to be used to analyze the data must also be determined. Then, it will be possible to precisely assess the interest of using first metatarsal bones instead of tibias for Harris lines studies in bioarchaeological studies, or perhaps to definitively acknowledge that Harris lines have no scientific interest as stress markers.

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