Harris Lines as Indicators of Stress in Prehistoric Illinois Populations

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Alan H. Goodman
George A. Clark
Department of Anthropology
University of Massachusetts

Introduction

Radiographs of tubular bones, round bones and epitheses often reveal lines and bands of increased opacity. These increased opacities are essentially trabeculae oriented at right angles to the cartilaginous surface which result in increased mineralization and mineral density (Garn et. al., 1968). This phenomenon has been given a variety of names: transverse lines, growth arrest lines, lines and bands of increased density, Harris lines, bone scars. In this paper we will call these phenomena Harris lines or simply lines, a widely used convention after one of the first researchers to extensively report on the causes of the phenomena (cf., Harris, 1933).

Harris lines have been associated with a wide variety of environmental stressors including marasmus, kwashiorkor, vitamins A, C and D deficiencies, scarlet fever and infantile paralysis (Park, 1964). These stressors seem to commonly elicit episodes of growth disruption in which cartilage cell division slows or stops while mineralization continues, thus leaving behind layers of bone with increased mineralization and radiopacity. Because there appears to be a common mechanism of Harris line formation, triggered by a wide variety of stressors, these lines and bands should be useful as general indicators of stress.

The purpose of this research is to use Harris lines as indicators or "memory" of previous growth disruption and stress in an archeological population. Results will be presented on the frequency of lines in the distal and proximal tibias of the Dickson

Mounds Population (Lewiston, Illinois; 950-1300 A.D.). In addition to presenting the overall frequency of lines, we will investigate: 1) the association between the frequency of lines and demographic parameters (age, sex and cultural horizon), 2) the association between frequency of lines and length of tibia, 3) the distribution of lines with respect to developmental age or age at which growth disruption/stress occurred, and 4) the distribution of Harris lines over age as it relates to other indicators of stress such as enamel hypoplasias.

Population and Methods

The skeletal population used is from the Dickson Mounds. This site consists of both burial and habitation areas and is located near the confluence of the Illinois and Spoon Rivers, in Southwestern Illinois. The Dickson site was occupied by three successive cultural horizons: Late Woodland (@ 950-1050 A.D.), Mississippian Acculturated Late Woodland (@ 1050-1200 A.D.) and Middle Mississippian (@ 1200-1300 A.D.). The Middle Mississippian represents the culmination of trends toward: 1) increased population density and sedentarism, 2) extension and intensification of trade, and 3) a shift from a hunting-gathering economy to one based primarily on maize agriculture.

Previous research has hypothesized that morbidity and mortality would increase over time at Dickson due to the changes mentioned above. Lallo, Armelagos and Rose (1978) have recently summarized this research and conclude that an increase in infectious disease and mortality supports the hypothesis. Further support has been provided by Goodman, Armelagos and Rose (1980) who have found a significant increase in the number of individuals with enamel hypoplastic growth disruptions, a measure of general stress from birth to age seven. An increase in the frequency of Harris lines over time would give additional support to the hypothesis.

All available complete adult tibias were selected for radiographic analysis. The tibia was used because it exhibits a relatively high frequency of Harris lines (Garn et al., 1968; Park 1964), it is a commonly recovered bone, and it is the one most frequently used for analysis of Harris lines. In cases in which both of an individual's tibias were present, the one best preserved was selected for analysis.

The minimum criterion for recording the presence of a Harris line was that the line be a visible contrast of increased opacity extending across 1/4th or more of the tibial shaft. The method for determining the chronology of Harris line formation follows Clarke (1978), which considers differential growth rates between

males and females, between proximal and distal ends, and over developmental age. Clarke divides male and female tibial shafts into 33 sections of differing lengths--sixteen sections per proximal end and sixteen sections per distal end, corresponding to the first sixteen years of development, and a mid-shaft section corresponding to prenatal development. Age of line formation is determined by the section within the line lies.

Results and Discussion

In Table 1 are presented the means and standard deviations for the frequency of Harris lines per individual per proximal and distal tibias for the entire Dickson Population and the Dickson Population broken down by cultural horizon, age and sex. There are consistently more Harris lines on distal than proximal ends (approximately 2:1). This corresponds with the findings of other researchers. However, the precise reason why this occurs is still unknown (cf., Garn et al., 1968; Park 1964).

There is a mean of 1.68 lines per tibia (proximal and distal ends combined) for the total sample (Table 1). This mean falls within the range found by Wells (1967) for Anglo-Saxon populations --.8 to 5.1 lines per tibia. On the other hand, our overall mean is less than that found by McHenry (1968) who reports a mean of 8.01 lines per femur for a group of San Joaquin Valley California Amerindians. Nichens (1975), for a Mesa Verde Population, and Woodall (1968), for a Casas Grandes Population, have found fewer lines per tibia.

Differences between Dickson cultural horizons in the frequency of individuals with or without Harris lines on the proximal or distal tibia were tested for statistical significance (X^2 analysis, see Siegel, 1956). Differences were not found to be significant. Furthermore, as shown in Table 1, the trend is toward fewer lines per tibia over time. This trend runs counter to the other measures of pre-adult stress such as infant-child mortality rates and frequency of enamel hypoplasias performed on this population.

While males have more lines than females, differences were not statistically significant (X^2, Siegel 1956). The trend supports the view that the growing male is more susceptible to stress than the growing female because of the greater nutritional needs and smaller reserves. There are slight differences in the mean number of lines per tibia by age. Some evidence indicates that lines become resorbed in adulthood. For example, this is reflected by a lower frequency of lines in older adults. Again, this difference was not statistically significant by X^2 analysis.

A comparison of the length of tibias with one or more Harris lines, either distally or proximally, versus those without Harris lines is presented in Table 2. Females with Harris lines have significantly longer tibias than those without Harris lines (p .001 for both proximal and distal lines). This trend is also evidenced in males. However, it is not significant among males. When the sexes are combined, there is a significant difference between the length of tibias of individuals with and without proximal lines (p .05) but there is not a significant difference in length for distal lines. Generally then, individuals with longer tibias, the presumably taller individuals, have more lines than individuals with shorter tibias. This result runs counter to that found for Guatemalan children by Blanco et al. (1974). For the Indian Knoll population Perzigian (1977) implies also that there is an inverse relationship between Harris lines and adult stature.

The distribution of Harris lines in relationship to the time of their formation for the total Dickson sample is presented in Figure 1. The distribution of proximal lines shows a peak at around three years of age. The distribution of distal lines is less regular with two peaks. The first and taller peak occurs around two years of age and the second shorter peak occurs around thirteen hears of age. The earlier peak is very close to that found for enamel hypoplasias of the permanent population in a different sample from the same population (Goodman, 1976). The mean age of hypoplasia formation is 2.75 years of age. Although the relationship between the occurrence of Harris lines and enamel hypoplasias should be analyzed more directly, the results do support the view that these general indicators of stress have common causes. Furthermore, we propose that the distribution of Harris lines over age provides additional evidence that there is a great deal of stress during weaning in this population (Goodman, 1976).

Figure 2 shows the distribution of Harris lines by age of occurrence for the distal tibias in the Mississippian Acculturated Late Woodland and the Middle Mississippian. Figures 3 and 4 present similar distributions with comparisons of younger and older individuals and males versus females. The shape of these graphs remains rather constant by culture and age. However, males show a greater number of earlier lines than do females while females show a greater number of later lines than do males.

Conclusion and Summary

The relationship between Harris line frequencies and adult tibial length and Harris line frequencies and cultural horizon needs further examination. In the future, we will look for changes

in these relationships when severity is accounted for and in sub-adult and adolescent samples. At present, it appears that the larger Dickson individuals were most likely to show evidence of growth disturbance, perhaps due to their greater nutritional needs. This relationship overshadows any cultural differences in stress levels.

Finally, we would like to comment on the evidence for stress in the Dickson populations during the first and third years of life. The greatest frequency of both Harris lines and enamel hypoplasias occurs during the third year of life while the frequency of both of these indicators is much lower during the first year of life. Conversely, mortality is greatest in the first year of life and much lower in the third year of life. We propose that these differences are explained by the following host resistance factors and differences in sampling. Severe stress to Dickson infants during their first year of life is likely to lead to their deaths. These dead individuals become part of the sub-adult population. Because of increased host resistance, stress to Dickson two and three year olds is less likely to result in their deaths, but is still likely to cause a great deal of physiological disruption. Such disruptions are evidenced in sub-mortality indicators of stress such as enamel hypoplasias and Harris lines. These individuals had a greater chance of reaching adulthood than did their mates which were stressed earlier in life. They are therefore more likely to be included in the adult portion of the population and the sample utilized in this paper.

Acknowledgements

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TABLE 1

HARRIS LINES IN THE DICKSON MOUNDS POPULATIONS: Means and Standard Deviations for the Number of Lines on Distal and Proximal Tibias.

SAMPLE	DISTAL TIBIA Mean	DISTAL TIBIA Standard Deviation	PROXIMAL TIBIA Mean	PROXIMAL TIBIA Standard Deviation
BY CULTURE:				
Late Woodland (10)	1.30	(1.49)	0.70	(1.88)
Mississippian Acculturated Late Woodland (47)	1.19	(1.33)	0.49	(1.00)
Middle Mississippian (51)	1.06	(1.22)	0.57	(1.03)
BY AGE:				
15 to 39 Years (40)	1.38	(1.30)	0.75	(1.43)
40 to 60 Years (30)	1.23	(1.19)	0.57	(0.73)
BY SEX:				
Females (43)	1.21	(1.23)	0.53	(0.98)
Males (65)	1.46	(1.30)	0.74	(1.33)
TOTAL SAMPLE (130)	1.13	(1.27)	0.55	(1.12)

TABLE 2

TIBIAL LENGTH OF INDIVIDUALS WITH NO HARRIS LINES VERSUS THOSE WITH ONE OR MORE

SAMPLE		TIBIAL LENGTH Mean (mm)	TIBIAL LENGTH Standard Deviation	F-ratio	P (2-Tailed)
I. Total Adult Population.					
A. Distal.					
1. No Lines	(37)	35.270	2.870	1.17	0.615
2. Line(s)	(75)	36.937	3.103		
B. Proximal.					
1. No Lines	(72)	35.620	2.761	1.79	0.033
2. Line(s)	(40)	37.820	2.596		
II. Males.					
A. Distal.					
1. No Lines	(13)	37.285	2.761	1.33	0.472
2. Line(s)	(48)	37.629	2.397		
B. Proximal.					
1. No Lines	(36)	36.956	2.295	1.16	0.676
2. Line(s)	(25)	38.420	2.472		
III. Females.					
A. Distal.					
1. No Lines	(15)	34.620	1.591	5.76	0.001
2. Line(s)	(27)	35.707	3.817		
B. Proximal.					
1. No Lines	(27)	34.485	1.680	7.58	0.000
2. Line(s)	(15)	36.820	4.627		

FIGURE 1

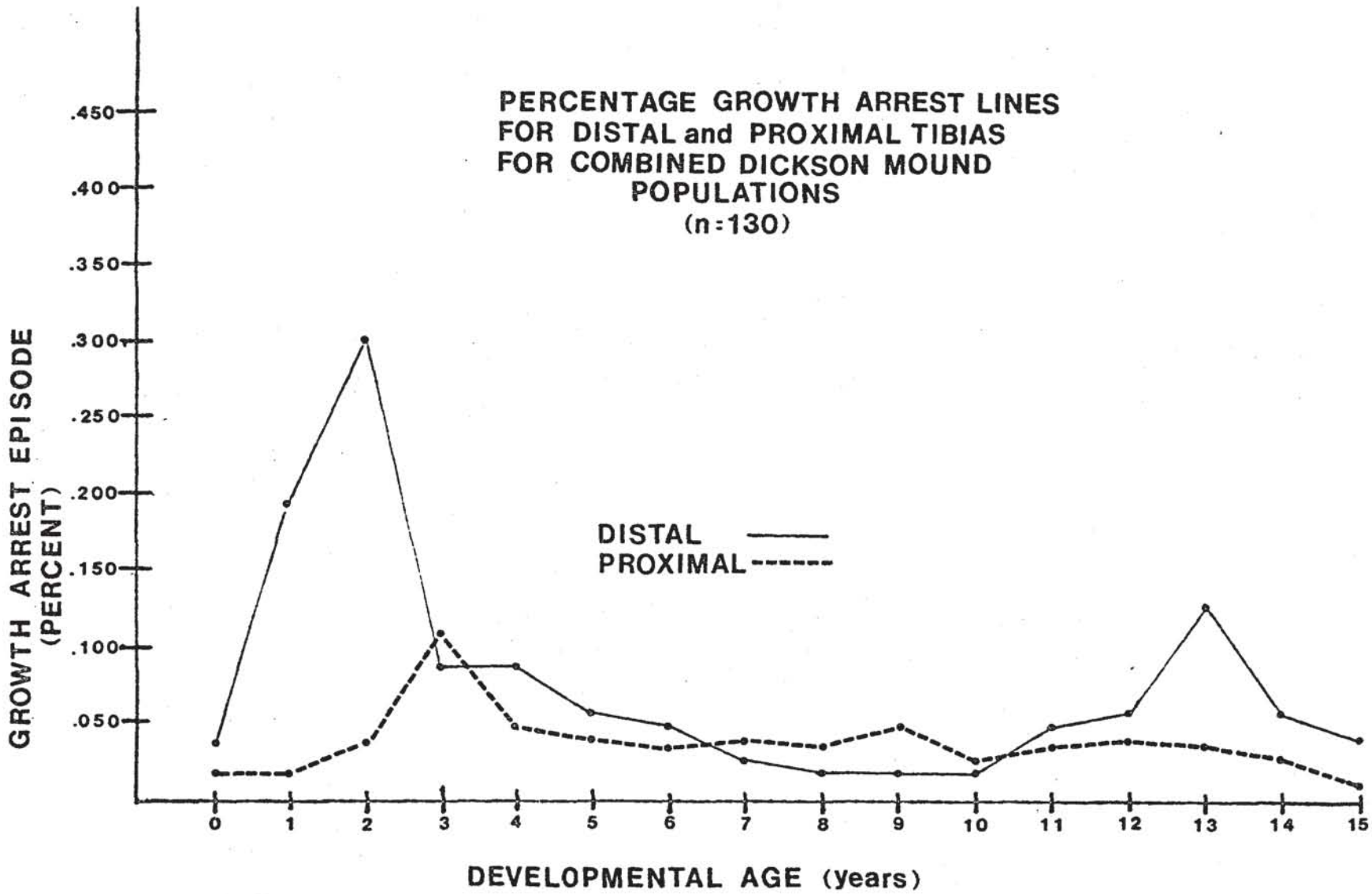

PERCENTAGE GROWTH ARREST LINES
FOR DISTAL and PROXIMAL TIBIAS
FOR COMBINED DICKSON MOUND
POPULATIONS
(n=130)
GROWTH ARREST EPISODE
(PERCENT)
.450
.400
.350
.300
.250
.200
.150
.100
.050
DISTAL
PROXIMAL
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
DEVELOPMENTAL AGE (years)

FIGURE 2

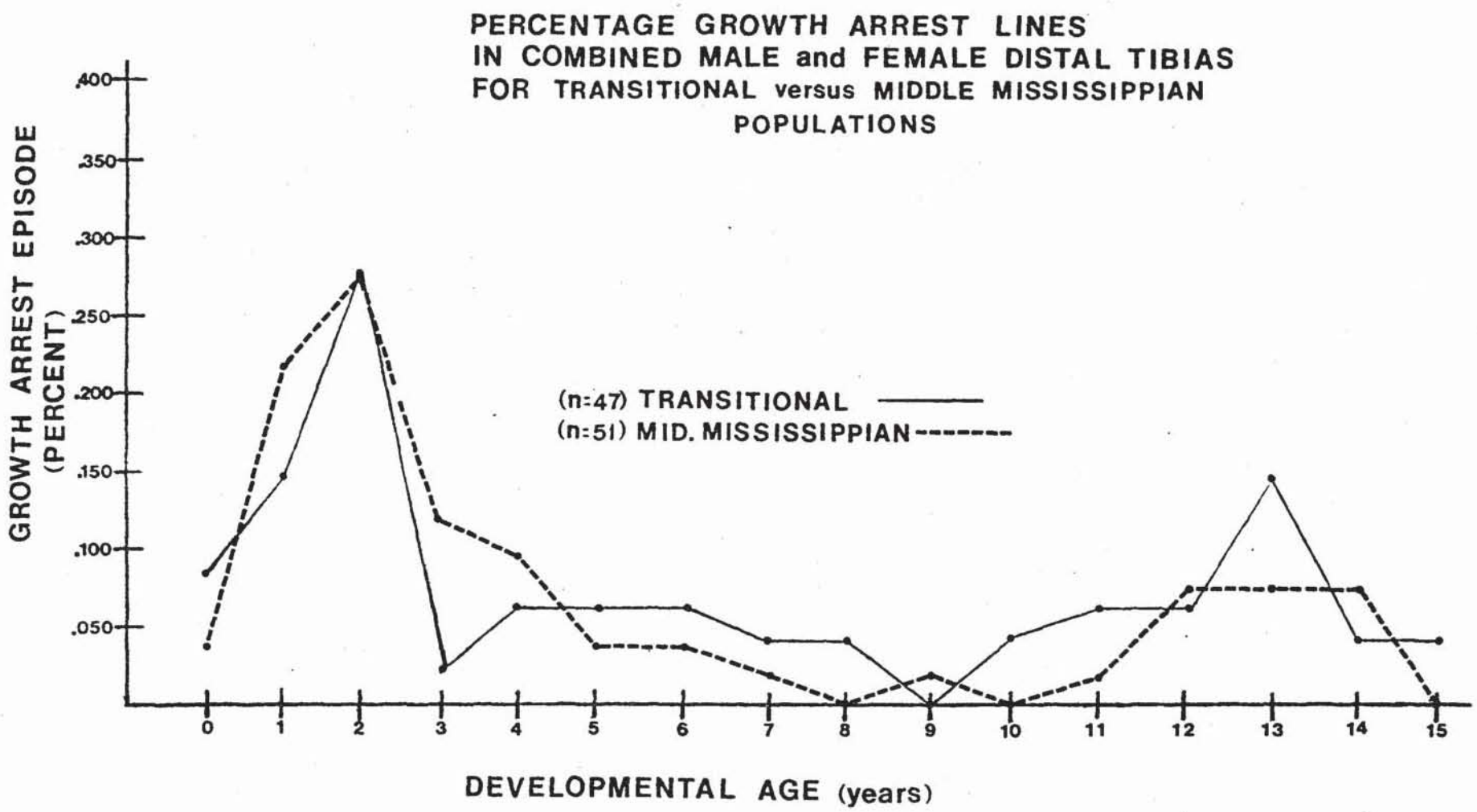

PERCENTAGE GROWTH ARREST LINES
IN COMBINED MALE and FEMALE DISTAL TIBIAS
FOR TRANSITIONAL versus MIDDLE MISSISSIPPIAN
POPULATIONS
GROWTH ARREST EPISODE
(PERCENT)
.400
.350
.300
.250
.200
.150
.100
.050
(n=47) TRANSITIONAL
(n=51) MID. MISSISSIPPIAN
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
DEVELOPMENTAL AGE (years)

FIGURE 3

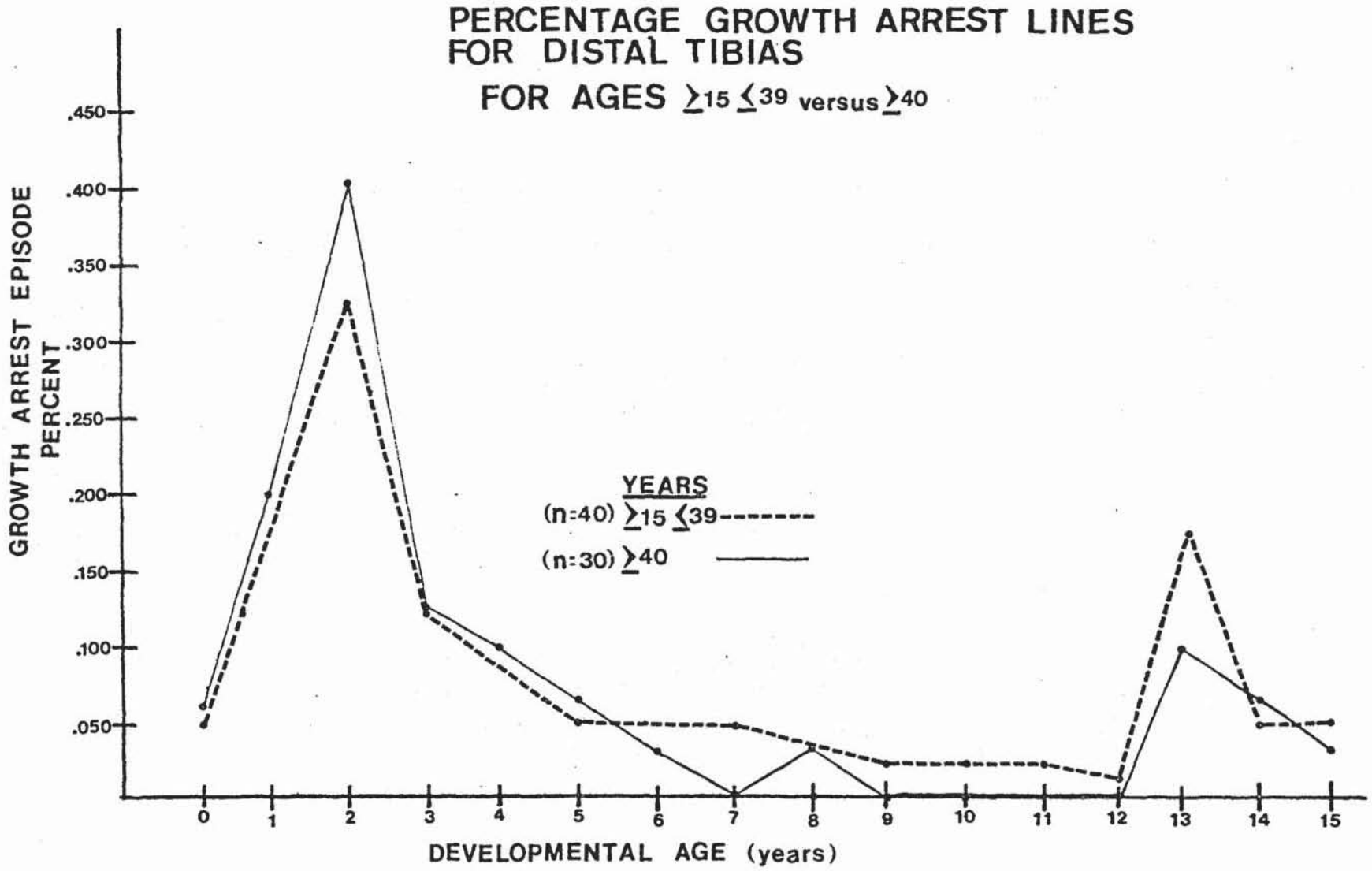
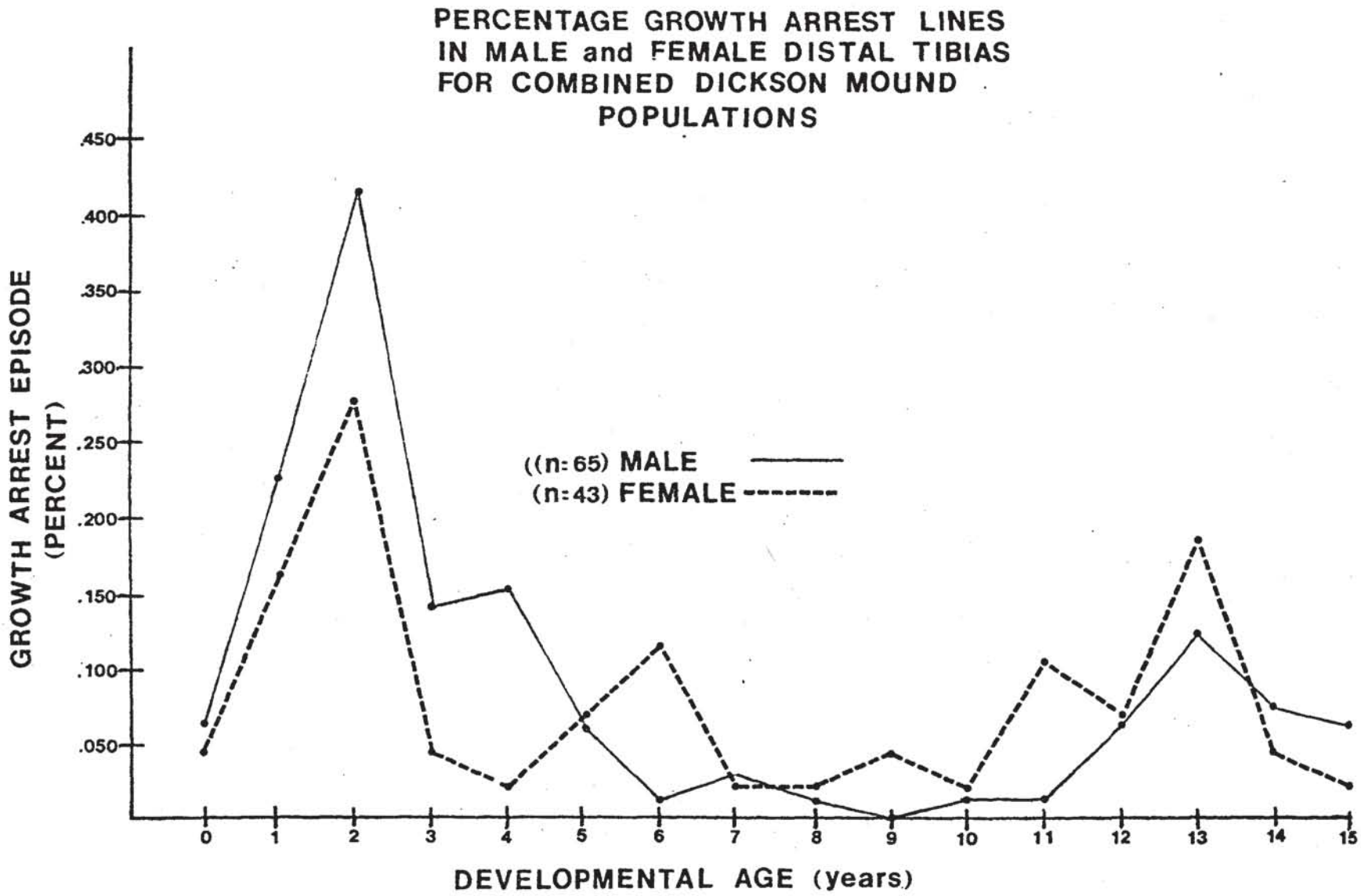

PERCENTAGE GROWTH ARREST LINES
FOR DISTAL TIBIAS
FOR AGES ≥15 ≤39 versus ≥40
GROWTH ARREST EPISODE
PERCENT
.450
.400
.350
.300
.250
.200
.150
.100
.050
YEARS
(n:40) ≥15 ≤39
(n:30) ≥40
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
DEVELOPMENTAL AGE (years)

FIGURE 4


PERCENTAGE GROWTH ARREST LINES
IN MALE and FEMALE DISTAL TIBIAS
FOR COMBINED DICKSON MOUND
POPULATIONS
GROWTH ARREST EPISODE
(PERCENT)
.450
.400
.350
.300
.250
.200
.150
.100
.050
((n:65) MALE
(n:43) FEMALE
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
DEVELOPMENTAL AGE (years)