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Author(s): Lesley Harrington and Susan Pfeiffer
Source: *The South African Archaeological Bulletin*, Vol. 63, No. 188 (Dec., 2008), pp. 95-101
Published by: South African Archaeological Society
Stable URL: http://www.jstor.org/stable/20475004

Research Article

JUVENILE MORTALITY IN SOUTHERN AFRICAN ARCHAEOLOGICAL CONTEXTS

LESLEY HARRINGTON[1] & SUSAN PFEIFFER[1,2*]
[1]*Department of Anthropology, University of Toronto, Canada*
E-mail: l.harrington@utoronto.ca
[2]*Department of Archaeology, University of Cape Town, South Africa*
**Corresponding author. E-mail: susan.pfeiffer@utoronto.ca*

(Received May 2008. Revised September 2008)

ABSTRACT

Estimates of age at death that are both accurate and precise can provide information about the patterns and causes of premature mortality in both Later Stone Age and Iron Age archaeology. Assuming a link between subsistence and health, differences in patterns of childhood growth are hypothesized. The best source of this information comes from the formation of tooth crowns and roots. Through the study of femur shafts from Later Stone Age juvenile skeletons, it can be demonstrated that linear growth was normal in tempo. The study of femora from a smaller number of Iron Age juvenile skeletons suggests that growth in this group did not follow a normal pattern, perhaps because prolonged ill health preceded death. Growth of Iron Age children who failed to reach adulthood appears to be variable but slow and this may provide insights into the Iron Age biosocial environment. Because of the demonstrated correlation between dental development and femur shaft length, the Later Stone Age juvenile long bone lengths provided here can be used in Later Stone Age contexts to estimate chronological age at death if dental information is unavailable. This approach should not be used in Iron Age contexts, since such an approach is likely to yield biased (under-aged) estimates of age at death.

Keywords: Later Stone Age, Iron Age, long bones, dental development, osteology, childhood, health.

INTRODUCTION

The documentation and analysis of juvenile human skeletons can provide information about the challenges and successes of past populations. From a demographic perspective, the proportion of immature skeletons can contribute to understanding mortality and fertility (Wood *et al.* 1992; Bocquet-Appel 2002). From a bioarchaeological perspective, the presence of juvenile skeletons in archaeological contexts can provide insights into crucial subsistence decisions about infant feeding (Clayton *et al.* 2006), into the management of disability (Pfeiffer & Crowder 2004), and into the roles that children of different ages played in past societies (Huffman & Murimbika 2003; Baxter 2005; Lewis 2007).

It is a fundamental premise of bioarchaeology that differences seen among past societies in their patterns of illness and death reflect differences in their subsistence approaches (Cohen & Armelagos 1984; Larsen 1997; Cohen & Crane-Kramer 2007). Characteristics of social organization like the size of the community, the organization of housing, the handling of waste, the type and amount of food available, and other variables can all affect people's health. These are all ways in which the Later Stone Age foragers and the Iron Age farmers differed. Studies of Later Stone Age skeletons have reported healed fractures, osteoarthritis, possible interpersonal violence and congenital abnormalities, but among these studies there is a distinct lack of evidence for infectious diseases (Pfeiffer 2007). This pattern is consistent with small groups of physically active people who move frequently through a risky environment. Low population density, absence of domestic animals and minimal waste accumulation are factors that should minimize infectious agents. Iron Age farmers, on the other hand, lived in larger, more substantial settlements, in close proximity to their herds. These variables could support infectious diseases, as has been documented (Steyn & Henneberg 1995). Challenges like parasites and wild animals would have affected both groups, but specific factors relating to social organization could lead to differences in the causes of illness and death. Based on the premise that settled groups with animals will have more endemic diseases, we predict that Iron Age children will show more evidence of growth lag than Later Stone Age forager children will.

Steyn and Henneberg (1996) have reported that the children from the Iron Age site of K2 appear to have been growing well, and Steyn (1994) has noted fewer indicators of chronic stress at K2 than at the Later Stone Age site of Oakhurst (as reported by Patrick 1989). Indicators of chronic stress, like hypoplasias (cribra orbitalia and other indicators of anaemia), transverse radio-opaque lines on long bones (Harris lines) and enamel hypoplasia can show considerable inter-observer error, and are subject to variable interpretation. Both anaemia and growth arrest lines can be interpreted as positive indicators of recovery from stressors, rather than fatal distress (Lewis 2007). Thus, there is value in using an approach that assesses a simple measure of growth against well established standards.

The most accurate and precise way to estimate the age of an immature human skeleton is to assess the development of the dentition. The timing and pattern of dental development is less influenced by environmental factors than skeletal development is, and genetic differences among populations are slight (Smith 1991). When enamel histology cannot be assessed, the best information is based on well established crown and root formation standards (Smith 1991; Buikstra & Ubelaker 1994; Saunders 2008).

When dental material is not available, or when expert assessment is not available (in field settings, for example), long bone (diaphysis) lengths can be used to estimate juvenile age at death. This approach is based on assumptions about the timing and pattern of linear bone growth (defined as an increase in the length of a long bone). From birth, an infant will grow rapidly for about the first two years of life. During mid-childhood, linear growth continues, but at a slower pace. The adolescent growth spurt revisits the rapid growth rate of infancy and ends with epiphyseal (growth plate) fusion at the final, adult, skeletal size (Tanner 1978). Because girls begin puberty earlier and finish growing earlier than boys, a cross-sectional plot of linear growth with sexes combined shows a gradual increase in tempo in adolescence, rather than the pronounced, abrupt shift that each individual experiences. Because of the narrow range of normal birth size across human populations, linear dimensions of foetal and newborn skeletons can be compared to European reference values that draw on a very large sample size. However, as children grow they show more variability, based on both their genetic backgrounds and their environments.

Prior research has demonstrated that if age estimates are generated for Later Stone Age juveniles using North American values for linear growth, Later Stone Age children are significantly under-aged (Jerardino *et al.* 2000; Sealy *et al.* 2000; Pfeiffer & van der Merwe 2004). This is because they are growing toward a relatively short final adult stature. Skeletal development, in contrast to dental development, has a greater requirement for a population-specific reference group in its application to the estimation of age at death. Relatively few juvenile skeletons from Iron Age archaeological contexts have been reported. Since adult statures in Iron Age skeletal collections fall within the middle of the human population range (Steyn 1994), it might be assumed that age estimates for Iron Age juveniles could be based on linear growth values from any sample in which the adults are of 'average' stature. The research described here explores this topic further.

MATERIALS AND METHODS

Research into linear growth of archaeologically-derived skeletons usually focuses on the femur, since it shows the greatest absolute size change from birth to maturity. Femoral diaphyses from 58 Later Stone Age immature skeletons form the basis for this study. Only individuals with open femoral epiphyses and preserved teeth (for age estimation) were included. Reported measurements are of maximum shaft (diaphysis) length following standard osteometric methods (Buikstra & Ubelaker 1994). Where both left and right sides were complete, the average length was used. The skeletons are mainly derived from locales on and near the coast, plus some inland sites, in the southern (*n* =21), western (*n* =5) and eastern (*n* =31) Cape. They date from about 220 to 5900 uncalibrated years before present, and all are from Later Stone Age archaeological contexts. Sites include Matjes River, Oakhurst, Wilton, Byneskranskop, Modder River Mouth, Klasies River Mouth, Spitzkop, Kleinpoort, and several others. The data have been scrutinized for outliers, and none are apparent. There is no evidence for temporal or spatial patterning with respect to quality of linear growth (evaluated as femur length for age) in the Later Stone Age juveniles.

Age estimates for Later Stone Age juvenile skeletons are based on dental formation and eruption standards (Moorrees *et al.* 1963a,b; Ubelaker 1989). All preserved teeth were included to form an average dental age estimate for each individual. Loose but associated teeth were assessed based on crown or root development, whereas teeth situated in the alveoli were assessed according to phase of eruption. All estimations were made by one author (LH).

Information for the Iron Age juvenile skeletons, dating from circa AD 1000 to 1900, comes from published reports. Skeletons for which age estimates are based on dental development are from K2 (*n* =19; Steyn 1994), a group of Botswana sites (Toutswe, *n* =14; Mosothwane 2004), and five others from published reports. The five all come from the Steyn research group, who use methods of age estimation that are consistent with those used for the Later Stone Age juveniles. Sites include K2 (recently discovered infant UP84; Steyn *et al.* 1999), Simunye in Swaziland (SATU7; Ohinata & Steyn 2001); Malle near Rustenberg (UP74; Pistorius *et al.* 2002), Hoekfontein in Northwest Province (HKF/7; Nienaber & Steyn 2005), and the Hamilton farm on the Limpopo (UP138; Boshoff & Steyn 2000).

In order to assess the pattern of growth, the juvenile femoral lengths for the Iron Age and Later Stone Age southern African groups are compared to standards derived from the Denver Growth Study (Maresh 1943, 1955). This mixed-longitudinal radiographic study was conducted between 1935 and 1967, providing femoral diaphysis lengths for North American children aged two months to twelve years (Maresh 1970). The mean of the male and female diaphysis lengths for each Denver age cohort are used in our analysis. Studies of growth in archaeological contexts are limited to a pooled-sex approach because (morphological) sex estimation of immature skeletons has not been demonstrated with sufficient reliability.

Linear growth of the skeleton can be assessed in absolute terms (bone length). However, the variability observed in mean adult stature across populations suggests that the potential for absolute length in the long bones of any given child is mitigated by population-specific genetic and environmental factors. Our comparison of linear growth across groups considers femur length for age as a percentage of the mean femur length among adults of the same population (the 'adult endpoint'). A residual, relative to the percentage of adult femur length for each age achieved among North American children, is calculated (as per Humphrey 2000, 2003). Details of this analysis can be found in Pfeiffer & Harrington (in press).

The developmental pattern of linear growth, expressed as the percentage of adult femur length for age relative to a standard, illustrates differences in the tempo of growth across populations. Tempo of growth refers to the pace and patterning of the growth trajectory as evidenced by phases of lag or acceleration (Tanner 1978). In the context of archaeological skeletal samples, a growth trajectory is a composite of the growth achieved at the time of death among children in the group. This is in contrast to trajectories produced by longitudinal studies of living children, where not only are the children survivors, but the same children can be represented in successive cohorts.

The adult endpoint is a pooled-sex average of the mean male and female femur lengths for adults in a population. It is used to calculate the percentage of adult length achieved at each given age. For the Denver Growth Study, this value is based on femur lengths of the 18 year old male and female subjects in that study (489 mm, *n* =68). The mean femur length for Later Stone Age adults was calculated from values published by Pfeiffer & Sealy (2006, 405 mm, *n* =116) and is relatively balanced in females (*n* =56) and males (*n* =60). The Iron Age adult femur lengths include three from K2 (Maryna Steyn, pers. comm. 2008, 423 mm); eight from Toutswe (Mosothwane 2004, 472 mm), and four others from Late Iron Age sites: a male and female from Hoekfontein (HKF/1 and HKF/4; Nienaber & Steyn 2005); a female from Thulamela (UP43; Steyn *et al.* 1998), and male from Malle (UP73; Pistorius *et al.* 2002). In total, nine are from females and six are from males. Values are quite variable, with K2 contributing the shortest female (A 1722, 406 mm) and shortest male (A 1758, 428 mm). The pooled sex average is 457 mm. While this sample may not represent the true population mean, it is unlikely to overestimate it (Table 1).

RESULTS

Linear growth of femora, expressed in absolute size is illustrated in Figure 1. Femur lengths among North American and southern African infants fall within a narrow range, as expected. Later Stone Age and Iron Age children fall off the trajectory of growth recorded among Denver children by two years of age, and by mid-childhood all southern African children are at least one standard deviation below the mean

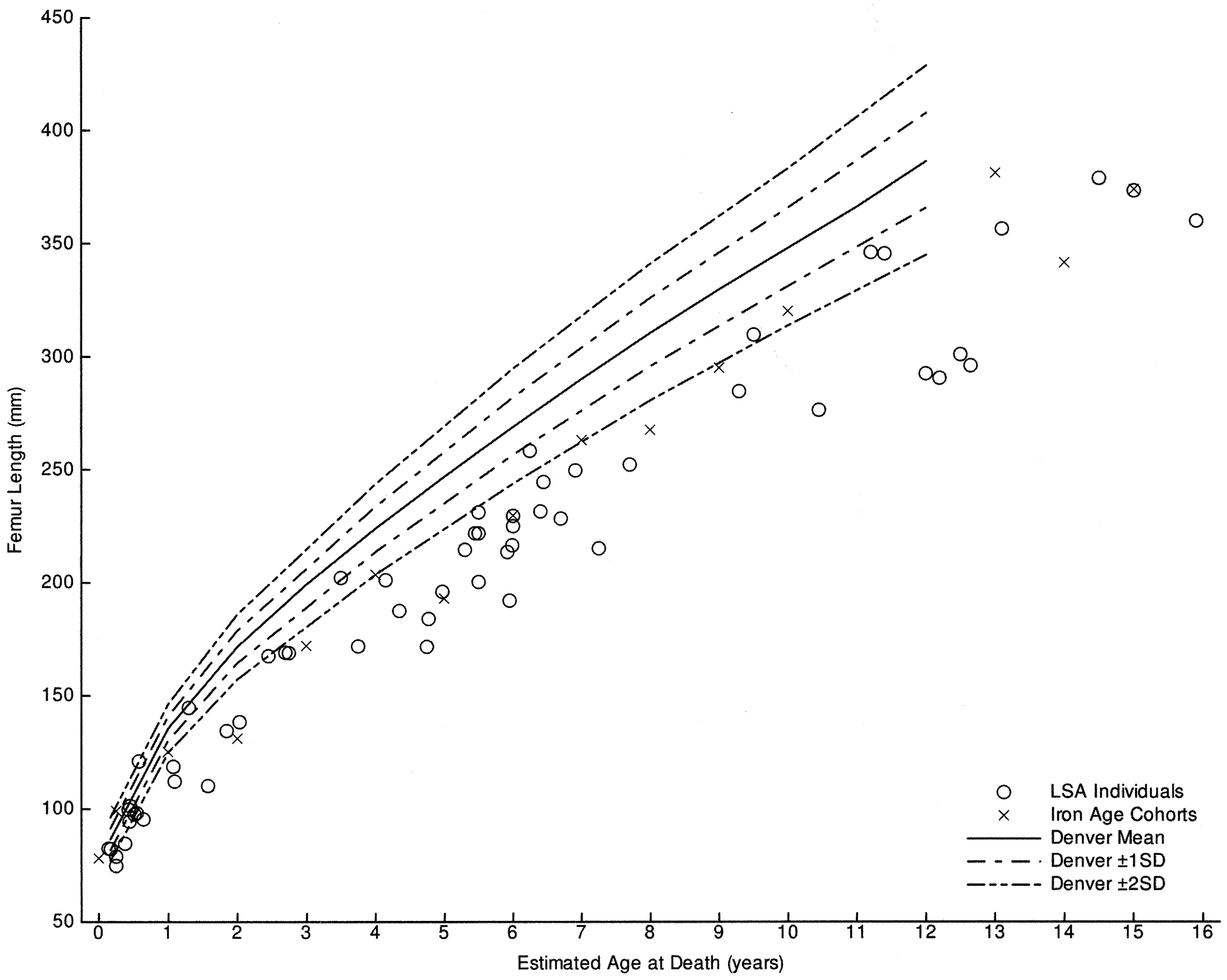

FIG. 1. *Femoral diaphysis length for age in Later Stone Age and Iron Age juveniles, relative to the Denver Growth Study. Markers for Later Stone Age represent individuals. Markers for Iron Age children from K2 and Toutswe are by year cohorts from* n = 1 *to* n = 5 *(see Table 2).*

femur length of modern North American children. Later Stone Age juveniles have the shortest femur lengths, illustrating a growth trajectory leading to a short-statured adult population. Iron Age femur lengths are generally (but not always) greater in absolute length, and would seem to be on a trajectory for taller adult stature relative to Later Stone Age individuals.

A comparison of femur length by age cohorts across groups (Table 2) illustrates that Iron Age juvenile femora are longer than those of the Later Stone age from mid-childhood onward, although cohort sample sizes are small; small mid-childhood cohort sizes are characteristic of archaeologically derived skeletal age distributions. Percentage adult femur length values, however, are greater in Later Stone Age children than in Iron Age children throughout the postnatal developmental period. Later Stone Age and Iron Age juveniles appear to have different patterns of growth overall, with Later Stone Age children achieving a greater proportion of the expected adult linear dimension at an earlier age.

Figure 2 illustrates these differences in growth tempo by plotting the percentage of adult size achieved at each age relative to a standard for the percentage of adult length attained, in this case, that of the Denver Growth Study. Points at the midline (0% residual) indicate that the percentage of adult size achieved at that age is the same as that achieved by North American children. Any deviations above and below the

TABLE 1. *Femur lengths for Iron Age adults, the pooled mean of which serves as the calculation by which the percentage of adult femur lengths by age is evaluated.*

Burial	Femur (mm)
Females	
A1730	428
A1722	406
Kgaswe B-55 2	415
Kgaswe B-55 26	448
Taukome 2	449
Thatswane 5	485
Toutswemogala 25	485
HKF/4	397
UP43	501
All females	446
Males	
A1758	428
Kgaswe B-55 5(2)	495
Kgaswe B-55 7(2)	481
Toutswemogala 22	486
HKF/1	470
UP73	450
All males	468
Total	
Pooled sexes	457

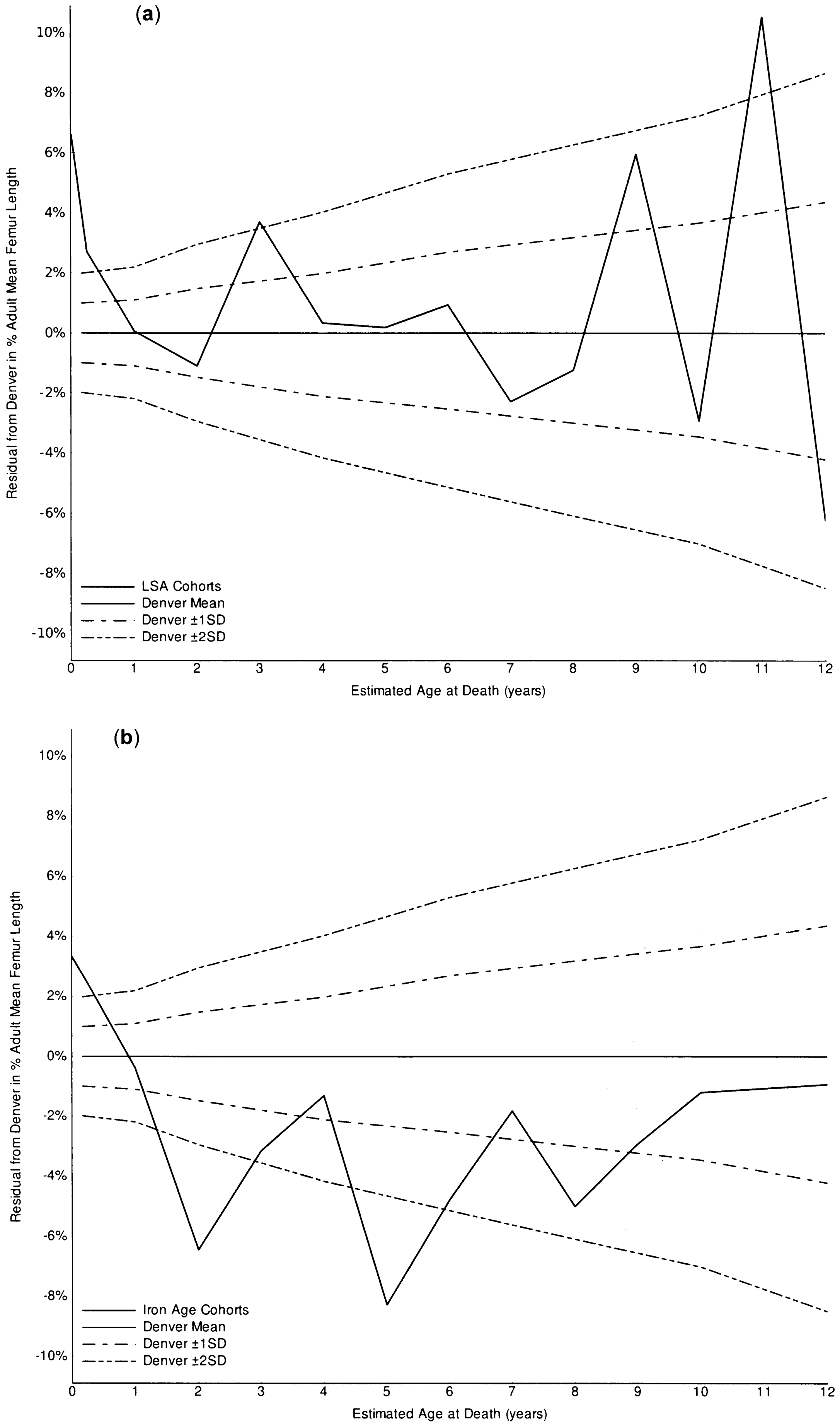

FIG. 2. *Residual percentage of adult femur length for age relative to the Denver Growth Study in Later Stone Age and Iron Age groups to 12 years of age. Points below the midline (0% residual) indicate a lag in growth relative to Denver, expressed as a percentage of the group-specific adult mean femur length.*

TABLE 2. *Femur lengths for Iron Age and Later Stone Age juveniles and from which the percentage of adult femur lengths is attained by age cohort.*

Age cohort (years)	Iron Age Femur length			LSA Femur length		
	n	(mm)	% adult	*n*	(mm)	% adult
0	5	78.0	17	2	82.3	20
0.25	5	99.2	22	6	88.9	22
1	5	125.0	27	7	112.5	28
2	2	131.0	29	4	137.6	34
3	1	172.0	38	3	179.9	44
4	5	203.5	44	3	186.7	46
5	1	193.0	42	8	205.1	51
6	4	229.6	50	8	226.3	56
7	2	263.0	58	3	230.9	57
8	2	267.5	59	1	252.0	62
9	1	295.0	64	2	297.0	73
10	1	320.0	70	1	276.2	68
11	–	–	–	2	345.8	85
12	–	–	–	3	294.7	73
13	1	381.3	83	2	326.2	81
14	2	341.5	75	1	379.0	94
15	1	374.0	82	1	373.5	92
16	–	–	–	1	360.0	89
Total	38			58		

line suggest an acceleration or lag in growth relative to the Denver sample. While this graphic approach extends only to age twelve, femoral lengths from older juveniles (Table 2) follow the same pattern, with Later Stone Age adolescents achieving a higher percentage of adult length than Iron Age adolescents. When the largest single Iron Age sample, the K2 juveniles, is considered separately relative to the K2 adult statures, they show the same pattern of growth lag.

Later Stone Age juveniles have percentage length for age values that are on or above the Denver mean in nine of the 14 age cohorts used in the analysis; in the remaining five cohorts they are below the mean. By contrast, eight of 10 cohorts available for the combined Iron Age sample have percentage femur length for age values that are below the Denver benchmark. During the first year, Iron Age and Later Stone Age infants have a greater proportion of adult femur length achieved, relative to North American children. We suggest that southern African children may have better growth outcomes during this developmental phase due to a practice of prolonged breastfeeding (later weaning) than was typical for mid-twentieth century North American infant care.

DISCUSSION AND CONCLUSIONS

This study used the length of the femur shaft (diaphysis) to explore general linear body growth. It compared the growth of Later Stone Age forager children to a smaller number of children from Iron Age archaeological sites. While small in absolute size, the growth of the Later Stone Age children demonstrates a pattern in pace that is consistent with healthy growth. When plotted relative to the acquisition of adult femoral length, the Later Stone Age children show values that are comparable to North American normative standards. Later Stone Age children do not appear to have experienced episodes of significant growth lag in the course of becoming relatively short-statured adults. Given the consistency of the patterns seen in the Later Stone Age linear measurements, we provide summary statistics (Table 3) from which researchers can estimate age at death when immature skeletal material is derived from a Later Stone Age context, if dental material is unavailable for age assessment.

The Iron Age children, while generally appearing larger for their ages than the Later Stone Age children, actually lagged behind the proportional growth that would be expected of them, once they were past infancy. When their femoral lengths are compared with the average Iron Age adult femoral lengths, their growth appears to have lagged prior to their death. It is not possible to say whether slowed growth was a characteristic of all children in the group, or only those who died. The simplest interpretation of the pattern seen here is that juvenile mortality in Iron Age communities was preceded by a period during which the child was failing to thrive, and that retarded growth was a characteristic of the fatal condition(s), not a characteristic shared by all children. Whether this pattern can or should be linked to the presence at various sites of apparent treponemal disease in at least Late Iron Age times (Nienaber & Steyn 2005), we cannot surmise. Parasitic infestation can affect growth, and Iron Age villages were positioned in proximity to both invertebrate and vertebrate vectors. Transmission of roundworm parasites (e.g. hookworm, pinworm, trichinosis) is supported by the presence of faecal debris and by working the soil. It could be argued that the failure to grow normally in the period prior to death reflects a social system that provided solicitous care to children who were not doing well. It may also form the basis for a hypothesis that fatalities from acute injuries, like poisoning and animal attacks, were rare. All these approaches are subject to further exploration, if large, well preserved samples become available.

Each of the Iron Age children deviates from the expected, normal growth pattern in the same direction (lagging), but the magnitude of that deviation is quite variable. Hence, we conclude that it would be inappropriate at this time to use any long bone growth 'standards' to estimate age at death for juvenile Iron Age skeletal material. It is particularly important that the estimation of age at death of Iron Age juvenile material should focus on the less environmentally labile information provided by development of the dentition.

The pattern of retarded growth preceding death is not seen in the Later Stone Age data. This is consistent with published research noting an absence of infectious disease. While signs of anaemia (cribra orbitalia) and growth arrest are present (Pfeiffer 2007), there are no signs of consistently slowed growth. This supports the developing view that these chronic stress indicators may reflect adaptation, rather than fatal distress. It may be relevant that the Later Stone Age population was well south of the malaria belt, and that transmission of roundworm parasites would have been less common due to the groups' mobility and subsistence pattern.

The results of this study suggest that causes of juvenile mortality were more likely to have been acute in the Later Stone Age context, and chronic in the Iron Age context. This research does not address the question of mortality risk. There are differences in the age distributions of the immature skeletons. Both groups have most of the juvenile mortality up to age six years, but the Iron Age group shows a peak in infancy while the Later Stone Age group shows a second peak at around five to six years that is equal in size to the infant group. This latter peak may be related to a much later weaning age among Later Stone Age children (Clayton *et al.* 2006). Since these skeletons come from archaeological sites that are spread over great expanses and hundreds of years, it would be inappropriate to treat them as 'demographic' samples. Nevertheless, the distribution of immature deaths is potentially relevant to our understanding of past lives. Here, too, more information will be very welcome.

TABLE 3. *Long bone diaphysis lengths for Later Stone Age juveniles, by age cohort. These data are presented following Saunders and colleagues (1993) for use as a comparative sample.*

			Femur				Tibia				Fibula			
Age cohort (years)	Mean age (years)	Cohort *n*	(mm)	*n*	S.D.	95% CI	(mm)	*n*	S.D.	95% CI	(mm)	*n*	S.D.	95% CI
0	0.12	6	82.3	2	0.1	0.2	68.9	4	2.1	2.1	64.0	4	1.9	1.8
0.25	0.34	10	88.9	6	11.1	8.9	75.6	6	8.9	7.1	65.2	5	7.0	6.1
1	0.88	8	112.5	7	17.6	13.1	94.2	6	16.2	13.0	86.3	6	14.2	11.3
2	1.94	5	137.6	4	23.5	23.0	113.6	4	20.2	19.8	100.5	3	15.4	17.4
3	2.98	3	179.9	3	19.1	21.6	154.9	2	21.7	30.1	147.7	2	22.3	30.9
4	4.08	3	186.7	3	14.7	16.6	148.0	2	9.7	13.5	141.3	2	12.0	16.6
5	5.24	9	205.1	8	20.7	14.3	169.5	8	20.4	14.1	166.5	5	15.9	13.9
6	6.08	9	226.3	8	20.1	13.9	183.6	5	19.6	17.2	180.9	5	20.0	17.5
7	6.91	5	230.9	3	17.4	19.7	198.6	4	25.9	25.4	178.5	3	13.6	15.4
8	7.61	2	252.0	1	–	–	–	–	–	–	223.0	1	–	–
9	9.39	2	297.0	2	17.7	24.5	242.6	2	16.8	23.3	215.5	1	–	–
10	10.45	1	276.2	1	–	–	227.0	1	–	–	217.5	1	–	–
11	11.40	2	345.8	2	0.4	0.5	293.8	2	6.7	9.3	267.0	1	–	–
12	12.23	3	294.7	3	5.6	6.3	247.5	3	14.9	16.9	233.0	3	6.1	6.9
13	13.06	3	326.2	2	42.8	59.3	319.5	1	–	–	308.0	1	–	–
14	–	–	379.0	1	–	–	–	–	–	–	–	–	–	–
15	15.00	1	373.5	1	–	–	316.0	1	–	–	299.0	1	–	–
16	15.95	2	360.0	1	–	–	318.0	2	11.8	16.4	–	–	–	–
17	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total		74		58				53				44		

			Humerus				Ulna				Radius			
Age cohort (years)	Mean age (years)	Cohort *n*	(mm)	*n*	S.D.	95% CI	(mm)	*n*	S.D.	95% CI	(mm)	*n*	S.D.	95% CI
0	0.12	6	66.6	6	4.4	3.5	55.0	4	2.7	2.7	59.6	4	5.8	5.7
0.25	0.34	10	73.0	8	8.7	6.0	65.6	6	8.0	6.4	58.6	7	6.8	5.0
1	0.88	8	88.9	8	12.9	9.0	68.7	7	10.6	7.9	77.0	4	14.1	13.8
2	1.94	5	105.3	4	17.0	16.7	77.4	3	11.2	12.7	91.7	4	13.8	13.6
3	2.98	3	137.2	2	20.9	29.0	105.2	2	19.7	27.3	119.0	2	21.3	29.5
4	4.08	3	141.0	2	6.4	8.9	101.6	2	13.3	18.5	112.0	3	9.9	11.2
5	5.24	9	145.4	9	13.7	8.9	112.0	7	12.0	8.9	122.8	8	12.5	8.6
6	6.08	9	157.5	7	15.6	11.6	121.3	7	8.5	6.3	133.6	5	10.8	9.5
7	6.91	5	167.3	3	22.5	25.4	124.6	3	12.3	13.9	142.9	4	15.6	15.3
8	7.61	2	186.6	1	–	–	143.0	1	–	–	156.9	1	–	–
9	9.39	2	190.0	1	–	–	158.1	2	20.0	27.7	170.1	2	24.9	34.5
10	10.45	1	199.2	1	–	–	141.6	1	–	–	158.2	1	–	–
11	11.40	2	241.9	2	5.5	7.6	194.0	2	2.8	3.9	179.5	2	2.1	2.9
12	12.23	3	203.7	3	8.2	9.3	152.9	3	6.4	7.2	166.9	3	6.9	7.9
13	13.06	3	223.8	2	28.6	39.7	177.5	2	36.1	50.0	196.2	2	35.0	48.5
14	–	–	–	–	–	–	–	–	–	–	–	–	–	–
15	15.00	1	272.0	1	–	–	208.0	1	–	–	–	–	–	–
16	15.95	2	281.0	1	–	–	–	–	–	–	242.0	1	–	–
17	–		–	–	–	–	–	–	–	–	–	–	–	–
Total		74		61				53				53		

ACKNOWLEDGEMENTS

The authors thank Maryna Steyn and Morongwa Mosothwane for providing access to their theses, and to Steyn for unpublished Iron Age adult femur length data. Louise Humphrey provided assistance with the Denver comparative plots. The comments of the *SAAB* reviewers were very helpful. We also thank the curators who provided access to the collections that form the basis of this research. They include Lita Webley and Johan Binneman (Albany Museum, Grahamstown), James Brink (Florisbad Research Station, National Museum, Bloemfontein), Alan Morris (University of Cape Town), Graham Avery and Sarah Wurz (Iziko Museums of Cape Town). Research support was provided to S.P. by the Social Sciences and Humanities Research Council (SSHRC) of Canada.

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