Cortical Bone Ontogeny: Activity, Nutritional Stress, and Archaeology

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Part I: Introduction:

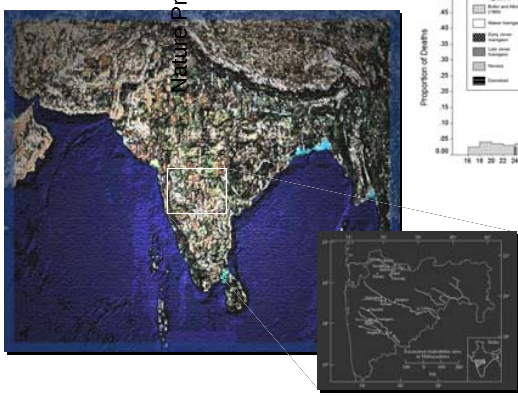
In the past two decades, research on growth in cortical bone cross-sectional parameters has suggested that:

1) Percent Cortical Area (total area - medullar area = %CA), once used to determine nutritional status from long bone cross-sections, declines as part of a ‘normal’ pattern of growth for the first three years of life.
2) Individuals that are developing in circumstances of adequate or excellent nutritional status demonstrate a decline in %CA that is accompanied by an increase in mass at the periosteal surface, which provides greater relative strength to the bone despite the thinner cortex.
3) An evaluation of relative strength in the humerus and femur demonstrates that the humerus increases in strength relative to the femur during the 6-12 month age category (when infants are generally beginning to acquire locomotor skills related to crawling) and then increases relatively faster in the femur after 12 months of age (when infants become more regularly bipedal).
4) Thus the general decline in %CA that people had previously interpreted as nutritional stress (e.g. Garn, 1970; Keith, 1984) was now explained as a function of normal growth.
5) Increasing levels of strength through infancy and childhood appeared to be more strongly correlated with body mass and activity levels, rather than nutritional status.

While this pattern of growth has been documented for populations of children with adequate nutritional status, growing up with relatively low levels of biocultural stress, does this pattern of growth vary in populations that experienced developmental stress?

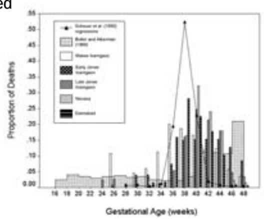
Part III: Materials:

Out of 300 individuals from 3 Chalcolithic villages (2000-700 B.C.) in India, 90% are under 5 years of age and 72 individuals have long bone lengths as well as dental ages (n = 137 humeri and femora). In this pooled sample (DC), 16 out of 72 (22%) individuals demonstrated evidence of growth suppression in long bone length (Z-scores < 2 standard deviations below the median for bone length for age). This pooled sample was evaluated against a sample of individuals from the Denver Longitudinal Study (n = 10 males and 10 females) whose cortical bone growth profiles were described previously (Ruff, 2003a, 2003b, 2005).

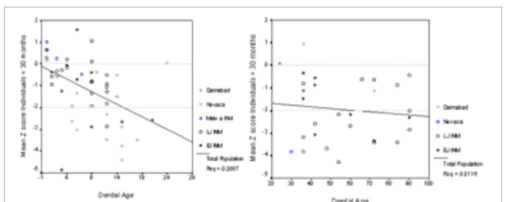


Sample of Long Bones from Infants and Children at Deccan Chalcolithic (DC) Sites

Site	Period	Ind < 120 mos	Ind with long bones	Ind with intact midshaft (cortical bone sample)	
				humerus	femur
Inamgaon	All INM	166	104	45	56
	Malwa	16	14	7	13
	EJ	43	32	8	13
	LJ	107	58	30	30
Nevasa	Jorwe	70	30	9	10
Daimabad	Jorwe	36	25	8	9
Total		**272**	**159**	**62**	**75**

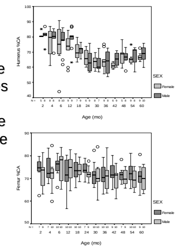


Bayesian Analysis of perinatal long bone lengths indicated that maternal-fetal health status was sufficient to buffer offspring from growth disruption during gestation. Graph shows low frequency of perinates with age estimates from long bone lengths that are < 35 lunar weeks (perinatal growth should be unaffected). Long bone linear growth suppression began after 3-6 months of age for Deccan Chalcolithic samples. 38% of individuals who died after the age of 30 months had low Z-scores for long bone length.

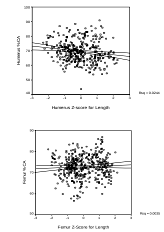


Part II: Cortical Bone Growth in the Denver Sample:

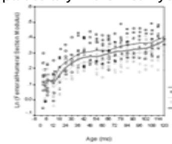
%CA (a standardized measure of cortical bone mass- TA – MA) declines for the first 3-4 years of life in the Denver sample individuals- as part of the expected growth profile.



The reference standard for long bone length for age was developed from the Denver sample (Maresh, 1970). Z-scores for humerus and femur length have no statistically significant relationship to %CA in these individuals.



The humerus acquires torsional strength (Zp) faster than the femur during infancy (particularly 6-12 months of age) and then the strength of the femur increases at a faster velocity after 12 months of age, particularly in the first 4 years.

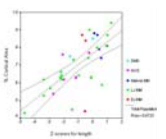


If this is the growth profile expected for infants and children growing up in circumstances of adequate nutrition, socio-sanitation conditions, and regular exercise, is the same pattern of growth maintained for infants and children that are experiencing nutritional and biocultural stress?

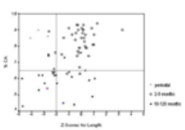
INM 122: enamel defect (LHPC) on upper and lower deciduous canines (lower right deciduous canine pictured above, photograph courtesy of John Lukacs).

Part IV: Results & Interpretation

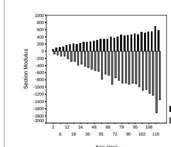
Unlike the Denver sample pattern, Z-scores for length do predict %CA in the DC sample (below). Low Z-scores for length (< -2 sd) are associated with reduced %CA.

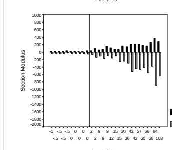


Both low Z-scores for length and very low %CA occur more frequently in DC individuals 12-60 months old (below).

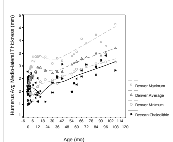


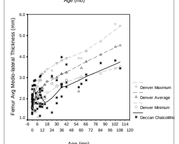
In the Denver sample, bone torsional strength (Zp) increases despite declines in %CA because mass is added at the periosteal surface (bone diameter increases). In the DC sample, strength does not increase as expected. This suggests that greater declines in %CA could be due to growth suppression at the periosteal surface. The humerus and the femur are both affected.



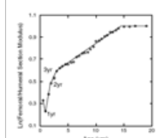


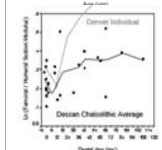
In the Denver sample, bone Mediolateral Diameter increases fastest during the first year of postnatal life. The velocity of growth slows 12-42 months. The diameter of long bones in the DC sample does not increase between individuals dying at 12 months and those dying at 3 years of age for the humerus or the femur.



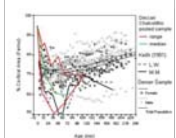


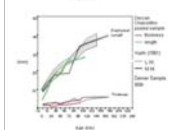
In the Denver sample, bone torsional strength (Zp) increases faster in the femur after 1 year of age. The pattern of growth differs in the DC sample. The femur grows in strength much more slowly relative to the humerus, suggesting that the femur is more sensitive to growth disruption in cortical bone properties than the humerus.





Although %CA is not the best way of examining growth in cross-sectional properties because it is a product of the variation in endosteal and periosteal envelopes, an evaluation of long bone length, cross-section properties (Zp and ML diameter) is informative about biocultural stress levels for subadult skeletal material.





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