J Forensic Sci, Apr. 1977, Vol. 22, No. 2

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Estimation of Stature in Children from Radiographically Determined Metacarpal Length

Forensic scientists and anthropologists have for a long time been concerned with practicable and reliable methods for estimating stature from bone dimensions. There are several rather reliable equations and tables for the estimation of adult stature, mostly from long limb bone lengths [*1*]; notable in this regard are those of Telkka [*2*], Trotter and Gleser [*3,4*], and Dupertuis and Hadden [*5*].

Few investigators have provided stature estimation equations from bone dimensions that are applicable to children. Telkka et al [*6,7*] have demonstrated that lengths of humerus, radius, ulna, femur, tibia, and fibula can provide estimates of Finnish children's stature with reasonable accuracy. Palkama et al [*8*] used femoral shaft diameter to estimate stature in Finnish children, but with considerably less accuracy than those estimations using the long bone lengths. For stature estimates other than these equations for Finnish children, one must interpolate from tables of age-specific means or percentiles of long bone lengths and stature for children from Boston [*9*] or Denver [*10–12*]. Also available are age-specific percentiles of long limb bone lengths expressed as a percentage of stature for Denver children [*13*]. However, the errors of estimation arising from interpolation from these tables are undetermined and probably rather large.

In a report of their investigations of second metacarpal growth, Gryfe et al [*14*] have suggested that second metacarpal length could provide an estimate of stature in children. The purpose of the present report is to determine whether radiographically determined second metacarpal length may be used as a reliable estimator of stature in children, thus providing an additional referent for forensic and archeological reconstruction.

Materials and Methods

The data consist of measurements of stature and 1597 left hand-wrist radiographs of 372 boys and 338 girls, 1 to 7 years of age, from rural Guatemala. The children are participants in a longitudinal study being carried out by the Division of Human Development at the Institute of Nutrition of Central America and Panama [*15*].

The Guatemalan children are typical of children in many underdeveloped countries where undernutrition is prevalent [*16*]. They are significantly shorter, lighter, and leaner

Received for publication 27 May 1976; revised manuscript received 19 July 1976; accepted for publication 22 July 1976.

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than children from better circumstances [*17,18*] and have significantly smaller metacarpal cortical dimensions than U.S. children of the same sex and age [*19*].

Stature was measured as recumbent length to the nearest millimetre throughout the age range as described in Yarbrough et al [*17*]. Hand-wrist radiographs were taken at each anthropometric examination as detailed by Himes et al [*19*]. Second metacarpal length was measured from the radiographs as the maximum dorsal length of the diaphysis in the midaxial plane as given by Roche and Hermann [*20*]. All metacarpal measurements were made by a single observer with a needle point, dial-read caliper to the nearest 0.05 mm. Anthropometric examinations were made within 7 days of the child's birthday.

The variability associated with the observer's measurement, as estimated by the standard deviation of differences from replicate measurements, is equal to 0.34 cm for stature [*17*] and 0.14 mm for metacarpal length.

Results

The sample size at each age and the means and standard deviations for metacarpal length and stature are presented in Table 1. The means for the length of the second metacarpal diaphysis (MII) of the Guatemalan children are significantly smaller ($P < 0.01$) than those reported for European children of the same age [*21*]. The boys are, on the average, taller than the girls at every age and have greater metacarpal length than girls from 1 to 5 years of age.

Stature was estimated from diaphyseal (MII) length across the age range for boys and girls by the method of least squares. The resultant prediction equations, the standard errors of estimate, and corresponding Pearson correlation coefficients for boys and girls, respectively, were these:

$$\text{Boys' stature (cm)} = 8.80 + 2.90 \text{ MII length (mm)} \pm 3.99; r = 0.95$$

$$\text{Girls' stature (cm)} = 7.90 + 2.89 \text{ MII length (mm)} \pm 3.90; r = 0.96$$

Given that the variability in stature at a fixed age is approximately 4 cm (Table 1), these equations are almost as precise at identifying groups of similar stature as is chronological age.

TABLE 1—*Means and standard deviations of metacarpal length and stature.*

Age Group, years	Boys					Girls				
		Metacarpal Length, mm		Stature, cm			Metacarpal Length, mm		Stature, cm	
	n	$\bar{X}$	σ	$\bar{X}$	σ	n	$\bar{X}$	σ	$\bar{X}$	σ
1	168	21.71	1.52	69.2	3.2	161	21.44	1.46	67.2	2.9
2	165	24.20	1.61	78.1	3.5	138	23.83	1.64	76.1	3.7
3	158	26.48	1.66	86.8	3.5	141	26.12	1.87	84.1	4.4
4	135	28.80	1.77	93.9	3.8	116	28.50	2.10	91.1	4.7
5	117	31.00	1.98	100.2	4.5	95	30.97	2.30	98.4	4.9
6	72	33.07	2.00	105.4	4.7	54	33.64	2.42	105.1	5.5
7	42	35.22	2.18	110.9	4.6	35	35.29	2.44	110.5	4.1

In Table 2 are presented the standard errors of estimate in estimating stature of children from the present series compared with errors of estimate reported in the literature for other bone lengths and femoral diameter. For girls, metacarpal length provides a

TABLE 2—*Standard errors of estimate for estimators of stature in children.*

Reference	Age Range, years	Estimator	SE_{est}, cm	
			Boys	Girls
Present series	1–7	metacarpal II	3.99	3.90
Telkka et al [*6,7*]	1–9	humerus	3.9	4.9
		radius	3.3	3.5
		ulna	3.1	5.1
		femur	4.1	4.1
		tibia	3.3	5.2
		fibula	3.1	5.0
Palkama et al [*8*]	0–15	femur (diameter)	7.1	7.5

better estimate of stature than any of the long bone lengths except radius. In boys, metacarpal length provides an equally good estimate of stature as femoral length; however, the other long bones estimate stature with smaller error than does the metacarpal, the best single estimator being the length of humerus.

Discussion

In the course of many health, nutrition, or growth studies standardized hand-wrist radiographs are taken, usually for the assessment of skeletal maturation. The radiographs provide a permanent record of the child that may be consulted at any time in the future. Metacarpal diaphyseal length may be reliably measured from radiographs, and radiographic measurements may be corrected for distortion [*22*], thus allowing for the calculation of separate equations applicable to skeletonized materials. Hence, there are many population-specific data available that might be used in providing stature estimation equations for children. Further, the relationships between stature and metacarpal length appear to be unaffected by environmental influences even as severe as clinical protein-calorie malnutrition [*23*]. Finally, the usefulness of this procedure may be seen in the residual error of approximately 4 cm, a figure similar to the variability in stature at a given age.

The appropriateness of an estimator of stature probably depends on the sex of the individual and the population from which the equations were derived [*2–4*]. There seems to be good evidence, at least in adults, that stature estimation equations derived from bone dimensions of one population are not universally applicable to other populations with the same degree of certainty [*2,4,24*]. Therefore, it is probable that the equations and estimates of errors presented in this report for the estimation of stature from second metacarpal length in Guatemalan children would not be numerically identical to those from other populations. However, we have demonstrated that second metacarpal length can be used as a practical estimator of stature in young children with reliabilities generally comparable to estimates from long bones.

Summary

Whether radiographically determined second metacarpal diaphyseal length could provide a reliable estimator of stature in children was investigated. The data consist of measurements of stature and 1597 left hand-wrist radiographs of children from 1 to 7 years of age from rural Guatemala. The errors in estimating stature in children from metacarpal length are comparable to those from equations estimating stature from long bones. It is concluded that second metacarpal length may be a reliable and practicable referent for the estimation of stature in children.

Acknowledgments

This research was supported by Contract PH43-65-640 from the National Institute of Child Health and Human Development, Bethesda, Maryland, and a research grant from the Institute of Latin American Studies, University of Texas at Austin, Austin, Texas. Thanks are extended to Dorothy Tart and Molly Schwinn for their help in manuscript preparation.

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