TECHNICAL NOTE

Hugo F.V. Cardoso,[1,2] Ph.D.

A Test of Three Methods for Estimating Stature from Immature Skeletal Remains Using Long Bone Lengths*

ABSTRACT:

the National Institute of Legal Medicine, also in Lisbon. As stanthe ages of 1 and 9 and children between 10 and 15 when using the technique described by Telkk et al. (11). All three methods provide sex-specific regression equations but only Feldesman (10) and Smith (1) provide equations for when sex cannot be determined. Simple differences between cadaver length and estimated stature were calculated to assess how closely estimates obtained from the three methods and from the different long bones are from true stature. Because some individuals did not preserve all the long bones, stature estimates reflect the preservation status of the sample.

Results and Discussion

Individual stature estimates obtained from each of the three methods are shown in Tables 1–3. Results are presented by individid-

TABLE 3—Estimates of stature according to the equations provided by Smith (1) for the length of the humerus, radius, ulna, femur, tibia, fibula, and femur + tibia.

Specimen	Age	Sex	Cadaver Length	H	95% CI	R	95% CI	U	95% CI	Fe	95% CI	T	95% CI	Fi	95% CI	Fe + T	95% CI
Regression equations for children of unknown sex																	
629	10.92	F	128	120.2	114.3–126.1	116.0	109.8–122.1	119.3	113.6–125.0	119.5	114.7–124.3	119.9	115.5–124.3	118.0	113.6–122.4	119.7	115.8–123.5
1533	7.08	M	115	117.4	111.5–123.3	116.6	110.4–122.8	116.9	111.2–122.6	115.1	110.3–199.9	111.1	106.7–115.5	111.8	107.5–116.2	113.3	109.4–117.1
570	7.75	M	123	–	–	–	–	–	–	117.2	112.3–122.0	116.7	112.3–121.1	116.9	112.5–121.3	116.9	113.1–120.8
1180	8.92	M	122	–	–	–	–	–	–	120.1	115.3–124.9	117.8	113.4–122.2	117.3	112.9–121.7	119.0	115.2–122.9
574	9.75	M	124	122.1	116.2–128.0	122.8	116.6–129.0	123.4	117.7–129.1	122.4	115.3–127.2	120.3	113.4–124.6	120.9	112.9–125.3	121.4	115.2–125.3
Sex-specific regression equations																	
629	10.92	F	128	120.4	113.7–127.0	116.8	110.4–123.1	120.0	114.2–125.7	119.8	115.3–124.2	119.9	114.9–125.0	118.0	112.8–123.3	119.8	115.7–123.9
1533	7.08	M	115	117.2	112.5–122.0	115.5	110.2–120.9	116.1	110.9–121.3	114.9	107.8–122.0	111.0	107.6–114.4	111.7	108.7–114.7	113.1	109.6–116.5
570	7.75	M	123	–	–	–	–	116.9	109.8–124.0	116.7	113.3–120.1	116.8	113.8–119.8	116.8	113.3–120.2	116.9	109.8–124.0
1180	8.92	M	122	–	–	–	–	119.8	112.6–126.9	117.8	114.4–121.2	117.2	114.2–120.2	118.8	115.4–122.3	119.8	112.6–126.9
574	9.75	M	124	121.9	117.2–126.6	121.8	116.4–127.1	122.6	117.4–127.8	122.0	114.9–129.2	120.3	116.9–123.7	120.8	117.8–123.8	121.3	117.8–124.7

H, stature obtained from humerus length; R, stature obtained from radius length; U, stature obtained from ulna length; Fe, stature obtained from femur length; T, stature obtained from tibia length; Fi, stature obtained from fibula length; Fe + T, stature obtained from femur + tibia length; 95% CI, 95% confidence interval. Cadaver length and stature values are in centimeters.

TABLE 4—Individual and mean differences between estimated and true stature for the three methods examined.

					Telkk et al. (sex specific)			Smith (sex specific)			Smith (unknown sex)		
Specimen	Age	Sex	Feldesman (sex specific)	Feldesman (unknown sex)	Mean	Upper Limb	Lower Limb	Mean	Upper Limb	Lower Limb	Mean	Upper Limb	Lower Limb
629	10.92	F	−23.2	−22.9	−6.7	−7.9	−5.4	−8.9	−9.0	−8.8	−9.2	−9.5	−8.9
753-A	13.92	F	−28.3	−28.8	−9.7	−8.1	−10.7	–	–	–	–	–	–
1534-A	1.17	M	–	–	0.9	0.2	1.5	–	–	–	–	–	–
1471	2.17	M	–	–	−8.4	−7.5	−9.3	–	–	–	–	–	–
1533	7.08	M	–	–	−3.0	−0.6	−5.4	−0.6	−1.3	−2.5	−0.2	2.0	−2.3
570	7.75	M	–	–	−9.4	–	−9.4	−6.2	–	−6.2	−6.1	–	−6.1
1180	8.92	M	−12.7	−13.3	−7.1	–	−7.1	−3.8	–	−3.8	−3.6	–	−3.6
574	9.75	M	−13.2	−13.8	−3.3	−3.4	−3.2	−2.4	−1.9	−2.9	−2.0	−1.2	−2.8
1564	14.17	M	−18.6	−17.8	−7.0	−6.7	−7.2	–	–	–	–	–	–

Using cadaver length as a proxy for true standing stature is, probably, an unlikely cause for the results in this study. Even if stature was measured in the cadaver as if it was considerably stretched, this would hardly explain differences of up to 28 cm between cadaver length and estimated stature. Uncorrected regression formula for radiographic magnification of long bone lengths in Telkk et al. (11) study may also be of some concern, but this would also be an unlikely explanation for such large differences between cadaver length and estimated stature. In addition, stature is consistently underestimated using all three methods, suggesting that the explanation may lie in the study sample itself. Inaccuracy of methods are, instead, likely to derive from differences in relative proportions of long bone length to body height between the children that contributed to the development of each method and the study sample children. The results suggest that the Lisbon children have proportionally shorter limb bones to stature than what would be expected from their stature estimates. In this respect, it is interesting to note that the regression equations devised by Smith (1) and Telkk et al. (11) are least accurate when estimating stature from lower limb bones, compared with upper limb bones. This means that the Lisbon children have particularly shorter legs explaining variations in growth status that can impact negatively on accuracy of stature estimation methods. The methods examined here have their origins in growth studies of well-nourished, well-cared-for children from either North America or Northern Europe and, as such, represent optimal rather than average or modal growth rates and cannot generate universally applicable methods. They represent neither the poorer children of their own societies, nor the underprivileged children of the developing nations. It has been shown that skeletal maturational delays related to socioeconomic differences between populations will make standards developed on the well-off children inapplicable to children of developing nations, as their skeletal ages will tend to underestimate true chronological age (55,56). The same rationale applies for stature estima-

28. Manouvrier L. Le d termination de la taille d′apr s les grand os des membres. M m de la Soc d′Anthropol de Paris 1893;4(II s rie):347–402.
29. Pearson K. Mathematical contributions to the theory of evolution: on the reconstruction of stature of prehistoric races. Philos Trans R Soc Lond (Biol) 1899;192:169–244.
30. Dupertius CW, Hadden JA Jr. On the reconstruction of stature from long bones. Am J Phys Anthropol 1951;9:15–54.
31. Krishan K, Kumar R. Diurnal variation of stature in three adults and one child. Anthropologist 2007;9:113–7.
32. Lampl M. Further observations on diurnal variation in standing height. Ann Hum Biol 1992;19:87–90.
33. Voss LD, Bailey BJR. Diurnal variation in stature: is stretching the answer? Arch Dis Child 1997;77:319–22.
34. Siklar Z, Sanli E, Dallar Y, Tanyer G. Diurnal variation of height in children. Pediatr Int 2005;47:645–8.
35. Giles E, Hutchinson DL. Stature- and age-related bias in self-reported stature. J Forensic Sci 1991;36:765–80.
36. Ousley SD. Should we estimate biological or forensic stature? J Forensic Sci 1995;40:768–73.
37. Himes JH, Roche AF. Reported versus measured adult statures. Am J Phys Anthropol 1982;58:335–41.
38. Braziuniene I, Wilson TA, Lane AH. Accuracy of self-reported height measurements in parents and its effect on mid-parental target height calculation. BMC Endocr Disord 2007;7:2.
39. Krogman WM. Child growth. Ann Arbor, MI: The University of Michigan Press, 1972.
40. Tanner JM. Fetus into man. Physical growth from conception to maturity. Cambridge, MA: Harvard University Press, 1978.
41. Buschang PH. Differential long bone growth of children between two months and eleven years of age. Am J Phys Anthropol 1982;58:291–5.
42. Buschang PH, Malina RM, Little BB. Linear growth of Zapotec schoolchildren: growth status and yearly velocity for leg length and sitting height. Ann Hum Biol 1986;13:225–34.
43. Tanner JM, Hayashi T, Preece MA, Cameron N. Increase in length of leg relative to trunk in Japanese children and adults from 1957 to 1977: comparison with British and with Japanese Americans. Ann Hum Biol 1982;9:411–23.
44. Frisancho AR, Guilding N, Tanner S. Growth of leg length is reflected in socio-economic differences. Acta Med Auxol 2001;33:47–50.
45. Bogin B, Smith P, Orden AB, Varela Silva MI, Loucky J. Rapid change in height and body proportions of Maya American children. Am J Hum Biol 2002;14:753–61.
46. Smith PK, Bogin B, Varela-Silva MI, Loucky J. Economic and anthropological assessments of the health of children in Maya immigrant families in the US. Econ Hum Biol 2003;1:145–60.
47. Bogin B, Rios L. Rapid morphological change in living humans: implications for modern human origins. Comp Biochem Physiol A Mol Integr Physiol 2003;136:71–84.
48. Cardoso HFV. Patterns of growth and development of the human skeleton and dentition in relation to environmental quality (PhD thesis). Hamilton, ON: McMaster University, 2005.
49. Cardoso HFV. Environmental effects on skeletal versus dental development: using a documented subadult skeletal sample to test a basic assumption in human osteological research. Am J Phys Anthropol 2007;132:223–33.
50. McCannon RW. Introduction. In: McCannon RW, editor. Human growth and development. Springfield: Charles C Thomas Publisher, 1970;3–19.
51. Stuart HC, Reed RB, Associates. Description of project. Pediatrics 1959;24:875–85.