TECHNICAL NOTE

Paul W. Sciulli[1] *and Richard O. Pfau*[2]

A Method for Estimating Weight in Children from Femoral Midshaft Diameter and Age

REFERENCE: Sciulli, P. W. and Pfau, R. O., "**A Method for Estimating Weight in Children from Femoral Midshaft Diameter and Age,**" *Journal of Forensic Sciences,* JFSCA, Vol. 39, No. 5, September 1994, pp. 1280–1286.

ABSTRACT: In this investigation, we relate transverse midshaft diameter of the femur, age, and weight in a sample of 183 children from Central Ohio. Age and femur diameter considered separately are similar in their ability to predict weight. Considering all sex and ancestry groupings (male, female, white, black), age explains between 90% to 96.8% of the variation in weight while femur diameter explains between 93% to 97.4%. However, estimates of individual weight from age or femur diameter have very large 95% prediction limits.

Using age and femur diameter together results in a greater proportion of the variation in weight explained, 97.7% for the total sample, but the 95% prediction limits are similar to those using femur diameter alone.

KEYWORDS: anthropology, children, weight, age, femoral diameter, human identification

In the identification of skeletal remains of children, age [*1*] and often ancestry [*1*] can be determined with a reasonable degree of accuracy. However, unless appropriate soft tissue is preserved, other physical features of children such as sex, hair and skin color and weight cannot be determined. Weight is routinely included in reports of missing children, but to date has received little attention by osteologists. The accurate estimation of the weight of a child from skeletal remains can be a valuable piece of information in identification, especially when used in conjunction with other physical features.

The purpose of this report is to present analyses that relates weight and femoral midshaft diameter and weight, femoral midshaft diameter, and age in a sample of children from Central Ohio.

Material and Methods

The sample consists of all subadults (age <20 years) brought to the Franklin County Ohio Coroner's Office between 1 July 1990 and 30 June 1991. The total sample is 186,

Received for publication 6 Aug. 1993; revised manuscript received 13 Oct. 1993; 30 Dec. 1993; 28 Feb. 1994; accepted for publication 3 March 1994.

[1] Professor of Anthropology, Department of Anthropology, The Ohio State University, Columbus, OH.
[2] Adjunct Assistant Professor, Department of Anthropology, The Ohio State University, Columbus, OH.

but three individuals of Asian ancestry are excluded due to the small size of the group, and two white males and two black males are excluded in the femoral analysis because of trauma to the femora. Age, sex, ancestry, and weight are available for each individual. Table 1 contains the age and sex distribution of the sample used in this study.

Medio-lateral or transverse femur midshaft diameter is obtained by measuring the maximum width of the femur midshaft to the nearest 0.1 mm from an X-radiograph of the leg. Errors due to radiographic enlargement are minimized by using correction factors calculated specifically for each radiograph [2].

The analyses consist of calculating a simple linear regression of the natural logarithm of weight (lbs) on the natural logarithm of femur midshaft diameter (mm), the simple linear regression of the natural logarithm of weight (lbs) on the natural logarithm of age (years), and the multiple regression of ln weight on ln age and ln femur midshaft diameter. The regression equations resulting from these analysis are transformed to original units by exponentation.

Results

Table 2 contains the results of the analysis of femur midshaft diameter and weight: regression equations, squared correlations, and the quantities needed for calculating 95% prediction intervals [*3*]. The squared correlation indicate a good fit for all subgroups (see also Fig. 1) with a minimum of 93% of the variation in weight explained by femur midshaft diameter in black females.

Table 3 contains predicted weights for given femur midshaft diameters using the equations in Table 2. As can be seen, although the 95% prediction limits are relatively narrow for the smaller femur diameters, the limits rapidly expand. In order to provide better prediction of weight, we included age along with femur midshaft diameter in a multiple regression.

The analysis of age and weight produces results similar to the analysis of femur midshaft diameter and weight: for ln-ln regression of weight on age, age explains between 90% to 96.8% of the variation in weight in the subgroups. But as in the case of femur midshaft diameter, predictions of individual weight based on age yield very wide 95% prediction limits in this case, for older individuals.

The regression of ln weight on ln age results in a significant proportion of the variation in weight determined by age, $F = 2857.8$. The increment in determination due to the addition of ln femur midshaft diameter is also significant $F = 274.3$, indicating that significant additional explanation of the variation in weight is achieved by adding femur diameter to age. Table 4 contains the multiple regression equations including both age and femur midshaft diameter and the quantities necessary for calculating 95% prediction intervals for individual estimates. Table 5 shows estimates and 95% prediction intervals for given ages and femur midshaft diameters, and Table 6 is the covariance matrix and mean vector for the logged variables in the total sample ($n = 179$).

TABLE 1—*Age and sex distribution of the sample.*

Age (years)	Black Female	Black Male	White Female	White Male	Total
0–2	9	8	26	37	80
2–6	1	3	1	11	16
6–12	1	3	1	7	12
12–20	2	22	12	35	71
	13	36	40	90	179

TABLE 2—*Linear regression equations for ln weight on ln femur midshaft diameter.* N *is sample size,* R^2 *is the squared correlation coefficient (also the ratio of the explained mean square to total mean square), RES MSQ is the residual or unexplained mean square, SSQ FD is the sum of squares of the femur diameter, and Mean FD is the average femur diameter for the group.*

Group	*N*	Equation	R^2	Res. Msq	SSQ FD	Mean FD
Black Males	36	$LN(wgt) = -1.207 + 1.800 \times LN(FD)$ $WGT = (0.299)FD^{1.800}$	0.958	0.049	11.970	3.067
White Males	90	$LN(wgt) = -1.328 + 1.842 \times LN(FD)$ $WGT = (0.265)FD^{1.842}$	0.978	0.029	32.810	2.773
Black Females	13	$LN(wgt) = -1.068 + 1.729 \times LN(FD)$ $WGT = (0.344)FD^{1.729}$	0.933	0.074	3.798	2.455
White Females	40	$LN(wgt) = -1.385 + 1.879 \times LN(FD)$ $WGT = (0.250)FD^{1.879}$	0.978	0.025	11.791	2.527
All Males	126	$LN(wgt) = -1.296 + 1.830 \times LN(FD)$ $WGT = (0.274)FD^{1.830}$	0.974	0.034	47.011	2.857
All Females	53	$LN(wgt) = -1.312 + 1.845 \times LN(FD)$ $WGT = (0.269)FD^{1.845}$	0.966	0.036	15.640	2.509
Total Sample	179	$LN(wgt) = -1.288 + 1.830 \times LN(FD)$ $WGT = (0.276)FD^{1.830}$	0.974	0.034	67.158	2.754

TABLE 3—*Predicted weights for given femur midshaft diameters (FD).*

	Weight (pounds)							
	Males			Females				
FD	White	Black	Both	White	Black	Both	Total Sample	95% Limits
5	5.14	5.42	5.21	5.14	5.56	5.24	5.24	(3.63, 7.59)
9	15.17	15.61	15.28	15.52	15.36	15.50	15.39	(10.66, 22.18)
13	29.86	30.25	29.94	30.98	29.01	30.55	30.16	(20.88, 43.52)
17	48.95	49.03	48.92	51.28	46.13	50.11	49.28	(34.03, 71.27)
21	72.24	71.72	72.01	76.28	66.48	74.00	72.54	(49.95, 105.20)
25	99.60	98.17	99.08	105.84	89.87	102.08	99.80	(68.53, 145.16)
29	130.91	128.23	130.00	139.89	116.16	134.24	130.95	(89.66, 200.00)
33	166.09	161.81	164.68	178.33	145.23	170.38	165.88	(113.27, 242.62)
37	205.06	198.81	203.03	221.10	177.00	210.42	204.51	(139.27, 299.92)

TABLE 4—*Multiple regression equations for predicting weight from femur midshaft diameter and age. The black female sample is not included because of the small sample size. For the total sample* (N = *179*)*, the quantities needed for 95% prediction intervals for individual weight estimates are: mean FD = 2.754, mean age = 0.812, unexplained standard deviation = 0.1729, Gaussian multipliers* $C_{11} = 0.0219$ $C_{22} = 0.2414$ $C_{12} = -0.0714$ (C_{11} *for age and* C_{22} *for FD*).

Group	*N*	Equation	R^2	Res. msq
Black Males	36	$LN(wgt) = -0.268 + 1.421 \times LN(FD) + 0.132 \times LN(Age)$ $WGT = (0.765)(FD^{1.421})(Age^{0.132})$	0.963	0.046
White Males	90	$LN(wgt) = -0.540 + 1.530 \times LN(FD) + 0.095 \times LN(Age)$ $WGT = (0.583)(FD^{1.530})(Age^{0.095})$	0.980	0.027
White Females	40	$LN(wgt) = 0.357 + 1.174 \times LN(FD) + 0.205 \times LN(Age)$ $WGT = (1.429)(FD^{1.174})(Age^{0.205})$	0.984	0.019
All Males[1]	126	$LN(wgt) = -0.452 + 1.493 \times LN(FD) + 0.106 \times LN(Age)$ $WGT = (0.636)(FD^{1.493})(Age^{0.106})$	0.976	0.031
All Females[2]	53	$LN(wgt) = 0.384 + 1.162 \times LN(FD) + 0.200 \times LN(Age)$ $WGT = (1.468)(FD^{1.162})(Age^{0.200})$	0.976	0.027
Total Sample	179	$LN(wgt) = -0.226 + 1.405 \times LN(FD) + 0.132 \times LN(Age)$ $WGT = (0.780)(FD^{1.405})(Age^{0.132})$	0.977	0.030

[1]Quantities needed for 95% prediction intervals: mean FD = 2.857, mean age = 1.115, unexplained standard deviation = 0.2487, Gaussian multipliers $C_{11} = 0.0312$; $C_{22} = 0.3354$; $C_{12} = -0.0989$.

[2]Quantities needed for 95% prediction intervals: mean FD = 2.5094, mean age = 0.0909, unexplained standard deviation = 0.1633, Gaussian multipliers $C_{11} = 0.0789$; $C_{22} = 0.9865$; $C_{12} = -0.2698$.

TABLE 5—*Predicted weights for given femur diameters and age.*

FD (mm)	Age (years)	Weight (pounds) Males White	Males Black	Males Both	Females White	Females Both	Total Sample	95% Limits Total Sample
5	0.05	5.15	5.07	5.12	5.12	5.23	5.15	3.65–7.27
9	0.40	15.41	15.39	15.34	15.62	15.70	15.50	11.01–21.82
13	2.50	32.20	33.04	32.27	35.02	34.73	33.08	23.45–46.67
17	7.00	53.52	55.42	53.72	59.27	58.28	55.20	39.13–77.87
21	10.00	76.50	78.44	76.48	81.72	80.01	77.92	53.30–109.80
25	12.00	101.63	102.94	101.15	104.10	101.62	101.97	72.43–143.54
29	14.00	129.43	129.72	128.32	127.89	124.53	128.20	90.98–180.66
33	17.00	160.65	159.91	158.86	154.89	150.33	157.71	111.92–222.25
37	19.00	193.42	190.93	190.69	181.20	175.68	187.95	133.11–265.38

TABLE 6—*Covariance matrix and vector of means of natural log transformed data. Total sample,* n = *179.*

	Weight	Age	Femoral Dia.	
Weight	1.2971	...	...	3.7508
Age	2.2547	4.1617	...	0.8118
Femoral Diameter	0.6903	1.2137	0.3373	2.7540

Discussion

The combination of femur midshaft diameter and age yields estimates of weight similar to that of femur midshaft diameter alone. For example, for a child of unknown sex and ancestry with a femur diameter of 13 mm, the weight estimated from the equation for the total sample in Table 2 is 30.16 lbs with a 95% prediction interval of (20.88 to 43.52) pounds. If the age of this individual is known, for example, 2.5 years, the weight estimate from the multiple regression equation for the total sample (Table 4) is 33.08 lbs with the 95% prediction interval of (23.45 to 46.67).

For children of unknown age, weight can be estimated by using femur transverse midshaft diameter (Table 2). Femur midshaft diameter and age each show similar relationships to weight and each result in similar predictions. However, in older children (age greater that approximately 6 years) with femur transverse diameters (FD greater than approximately 15 mm), prediction intervals based on age or femur transverse diameter are unacceptably large. This same problem holds for femur transverse midshaft diameter *and* age. Thus based on the present data, weight estimates from femur diameter alone or from femur diameter and age will have acceptable limits only for children less than or about 6 years of age (with FD's less than or about 15 mm).

If ancestry and sex cannot be determined from the skeletal remains, as is often the case with young children, the weight estimates based on the total sample appear to be appropriate in the case of femur midshaft diameter alone and in the case of FD and age since the estimates of weight from these variable are similar for the sexes and for blacks and whites. If sex only can be determined, then 95% prediction limits can be calculated with that data given in Table 2 or the bottom of Table 4. Prediction limits are not given for sex-ancestry combinations as they are substantially the same as the units for sex alone.

Although these results are derived from a specific population(s) from Central Ohio, further study may reveal a more general application for these results in the identification of missing children in the United States.

References

[1] El-Najjar, M. Y. and McWilliams, K. R., *Forensic Anthropology*, Charles C Thomas, Springfield, Illinois, 1978.

[2] Pfau, R. O. and Sciulli, P. W., "Method for Establishing the Age of Subadults," *Journal of Forensic Sciences*, Vol. 39, 1994, pp. 163–174.

[3] Sokal, R. R. and Rohlf, F. J., *Biometry*, Witt Freeman and Co., San Francisco, 1981.

Address requests for reprints or additional information to
Paul W. Sciulli
Ohio State University
Department of Anthropology
124 W. 17th Ave
Columbus, OH 43210