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Microscopic Determination of Age at Death in an Autopsy Series

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ABSTRACT: The core technique was used to estimate age at death in 54 forensic science cases. Femurs provided the most accurate age estimates, followed by tibiae, then humeri. Accurate age estimates were derived for two groups of individuals: younger than and older than 40 years of age. Certain skeletal abnormalities and conditions were found to affect the accuracy of this technique.

KEYWORDS: physical anthropology, human identification, musculoskeletal system, cortical bone cores, femurs, tibiae, humeri, osteon lamellae, Haversian canal

Recently, the core technique [*1*] was proposed as a method for estimating the age at death beyond 50 years of age in skeletons. The accuracy of this technique has been reported to be comparable to other histological techniques [*2-4*] but with the principal advantages of requiring small cores of cortical bone for analysis instead of complete cross sections and using an objective method of quantification. However, to date only data from a very small group (n = 8) of individuals for whom estimated and known ages at death were compared have been published by forensic scientists using the core technique [*1*]. The core technique has yet to be tested in a large series of forensic science cases that includes individuals in two groups: younger and older than 40 years of age. Forty years of age was used in this study to segregate individuals into two groups so as to include a group of females who were definitely premenopausal and a group that was circummenopausal and postmenopausal.

The purposes of this paper are these:

(1) to estimate age at death with the core technique in a series of forensic science cases that range in known age at death from 17 to 78 years of age;

(2) to assess the accuracy of the technique in white male and female forensic science cases and in small samples of blacks and Eskimos; and

(3) to demonstrate certain conditions in which the core technique fails to estimate accurately the age at death.

Methods

Cortical bone cores were obtained from a total of 54 individual forensic science cases ranging in age from 17 to 78 years of age. Bone cores, 0.4 cm in diameter, were taken from

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femurs of 28 individuals (19 males and 9 females); tibial cores were taken from 22 individuals (17 males and 5 females); and humeral cores were taken from 6 individuals (4 males and 2 females). In two cases bone cores were removed from both the femur and tibia, and thus there were 56 bone cores from 54 individuals. Mean known ages at death for individuals represented by each bone are presented in Table 1. The femoral core series contained samples from 22 whites, 3 blacks, and 3 Eskimos; the tibial cores, from 19 whites and 3 blacks; and the humeral core series, all from whites.

Core preparation followed procedures described by Thompson [1]. The bone sections mounted on microscopic slides were 85 μm thick and were analyzed with a phase contrast microscope at $\times$100. Age at death was estimated by quantifying the periosteal area containing secondary osteons. From regression equations (Eqs 5 to 12) presented by Thompson [1], age at death for each skeleton was estimated. The regression equations used were those that did not segregate individuals on the basis of cause of death, and therefore nonpathological and pathological individuals were grouped together. Although no significant differences in osteon remodeling between the right and left sides of the body for a given bone have yet been identified, the regression equations used to estimate age at death were those appropriate to the side of the body from which cores had been taken.

Results

The results from this study confirm the overall accuracy of the core technique in estimating age at death both in individuals older than 40 years and in those younger than 40 years.

Femurs yielded the most accurate age estimates, followed by tibiae, then humeri. Age estimates from white male femoral cores (n = 15) yielded a mean difference between known and estimated ages of 4.60 years and from white female femoral cores a mean difference of 3.29 years was obtained (Table 2).

Tibial cores yielded estimates of age at death that were less accurate than those from femoral cores. White males (n = 15) yielded a mean difference of 7.43 years for tibial cores, and white females (n = 5) yielded a mean difference of 4.60 years (Table 3). Blacks (n = 3) yielded a mean age difference for tibiae of 9.00 years, the same mean age difference as that found in the femoral core series from blacks (Table 4).

Cores from white humeri (n = 6) yielded estimated ages that poorly approximated known ages at death. A mean difference of 10.83 years was obtained for the humeral cores (Table 5). The sample of four males with a mean known age at death of 32.50 years yielded a mean estimated age of 39.25 years, a difference of 6.75 years, while the two female humeral samples yielded a mean difference of 19.00 years.

In comparing mean difference between known and estimated ages in all individuals older than 40 years with all those younger than 40 years, contrasts emerge. A mean difference of 3.00 years was obtained between all individuals older than 40 years (n = 9) while a difference of 6.21 years was obtained from femoral cores from all those individuals younger

TABLE 1—*Mean known age at death for each group.*

	Femurs		Tibiae		Humeri	
Sample	n	Mean Age, years	n	Mean Age, years	n	Mean Age, years
White males	15	36.07	14	51.43	4	32.50
White females	7	28.00	5	44.40	2	63.00
All blacks	3	34.67	3	37.00	...	...
All Eskimos	3	29.33	...	...	...	...

TABLE 2—*Known and estimated ages for white male and female femurs.*

Known Age, years	Estimated Age, years	Difference, years
	MALES	
18	17	−1
19	31	+12
19	19	0
20	24	+4
26	50	+24
29	31	+2
29	30	+1
35	39	+4
37	42	+5
45	51	+6
47	46	−1
48	45	−3
53	51	−2
56	54	−2
60	62	+2
Mean difference	...	4.60
	FEMALES	
17	12	−5
19	19	0
21	16	−5
23	23	0
25	22	−3
41	33	−8
50	48	−2
Mean difference	...	3.29

TABLE 3—*Known and estimated ages for white male and female tibiae.*

Known Age, years	Estimated Age, years	Difference, years
	MALES	
27	36	+9
28	33	+5
29	39	+10
29	35	+6
36	48	+12
47	51	+4
55	55	0
57	57	0
57	53	−4
67	55	−12
69	59	−10
69	59	−10
72	67	−5
78	61	−17
Mean difference	...	7.43
	FEMALES	
21	27	+6
26	28	+2
50	51	+1
61	56	−5
64	55	−9
Mean difference	...	4.60

TABLE 4—*Known and estimated ages for blacks and Eskimos.*

Sex	Known Age, years	Estimated Age, years	Difference, years
		BLACKS, FEMURS	
f	22	17	−5
m	25	46	+21
m	57	56	−1
		BLACKS, TIBIAE	
m	25	43	+18
m	36	43	+7
m	50	48	−2
		ESKIMOS, FEMURS	
m	23	23	0
f	30	53	+23
m	35	38	+5

TABLE 5—*Known and estimated ages for white male and female humeri.*

Known Age, years	Estimated Age, years	Difference, years
	MALES	
19	25	+6
29	25	−4
29	36	+7
53	39	−14
Mean difference	...	7.75
	FEMALES	
50	36	−14
76	52	−24
Mean difference	...	19.00

than 40 years ($n = 19$) (Table 6). Comparing differences between the estimated age and known age in the results from tibiae and the differences between individuals younger than and those older than 40 years yielded results similar to those found for femurs. A mean difference of 6.08 years was obtained from tibial cores from individuals older than 40 years ($n = 13$) and a mean difference of 8.33 years for individuals younger than 40 years ($n = 9$) (Table 6). Estimated ages at death obtained for individuals younger than 40 years generally exceeded known ages at death, while estimated ages for the group older than 40 years were generally less than the known ages. The mean differences between known and estimated ages were generally greater in individuals younger than 40 years than in individuals older than 40. This outcome may be explained on the basis of the series from which the age-estimating regression equations were generated: the mean known age at death was 72 years.

Incorporating information concerning pathologies and conditions known to affect cortical bone remodeling and thus the accuracy of age estimating illustrates certain shortcomings of the technique that were encountered in this forensic science series. In two cases represented by femoral cores in which estimated ages differed greatly from known ages, conditions were present in the skeleton that may, in part, account for inaccurate age estimations. In one case, a white female aged 41 years was estimated by the core technique to have been 33 years

TABLE 6—*Mean difference between known and estimated ages for individuals younger than and those older than 40 years of age.*

	Younger Than 40 Years		Older Than 40 Years	
Bone	*n*	Mean Difference, years	*n*	Mean Difference, years
Femur	19	6.21	9	3.00
Tibia	9	8.33	13	6.08

old. This difference of 8 years was the largest recorded for white females. The individual had had both feet amputated before her death. A second case, a black male aged 25 years, was estimated using the femur to have been 46 years of age. A core from the tibia of the same side also yielded an estimated age of 42 years. This individual was reported to have fractured his femur at its distal end. Healing had not been completed; rather, a callus remained.

In another case, in which the age at death was estimated at 56 years and the known age at death was 57 years, strikingly different structural relationships were found between the femoral secondary osteon perimeter and the Haversian canal perimeter. Extremely large Haversian canals, reflected by large perimeters and areas and "normal" secondary osteon perimeters and thus low osteon lamellae areas characterized this individual's periosteal femoral bone at midshaft. Mean Haversian canal perimeters of 0.40 mm and secondary osteon perimeters of 0.57 mm were recorded. This relationship is characteristic of an individual perhaps as old as 75 years; however, the total area occupied by secondary osteons (lamellae plus Haversian canals) was consistent with a person in his mid-50s. This individual was reported to have been alcoholic, emphysematous, and bedridden prior to death, any or all of which may have contributed to this histological configuration.

Discussion and Conclusions

The results obtained from the analysis of femoral cores are encouraging in that accurate age estimations were generally achieved. Results from the analysis of tibial cores also provided good estimations of age at death, while humeral cores yielded age estimations that are too inaccurate for forensic science applications. Differences are apparent between males and females with regard to the ability of this technique to estimate age at death. While the equations used to estimate age at death were generated from cores from individuals older than 40 years of age, their usefulness in estimating age at death in individuals younger than 40 years was also shown. However, differences in accuracy were noted.

The sample from whites was more accurately aged than the smaller samples from blacks and Eskimos, except in cases of known pathology or anomalies. This may be expected since the regression equations were established on U.S. whites. This study also revealed that injuries sustained prior to death influenced the accuracy of age estimations. In studies that attempt to demonstrate the accuracy of a technique to estimate age at death, individuals cannot be excluded a priori based on expected or observed pathology because of the likelihood of a forensic scientist's receiving material from a case that has been improperly diagnosed or has unnoticed conditions.

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