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Estimation of Stature from the Length of the Cervical, Thoracic, and Lumbar Segments of the Spine in American Whites and Blacks

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ABSTRACT: In order to estimate stature from the length of cervical, thoracic, lumbar, thoraco-lumbar (T-L) and cervico-thoraco-lumbar (C-T-L) segments of the spine, measurements were made on white and black Americans, both male and female, autopsied during 1977–1993. Sample sizes were as follows: white males = 167; white females = 58; black males = 43; black females = 31. Separate measurements were made of the vertebral segments along the anterior surface of the spine. Regression formulae were calculated for each segment in each of the four groups. Standard errors of estimate ranged from 2.60 to 7.11 cm. Comparison was made with previous work published for Japanese. The Japanese formulae could not predict stature of the American populations using our data. The method is useful for estimating the stature of severely burned or mutilated bodies.

KEYWORDS: physical anthropology, stature estimation, spine, whites, blacks

The law enforcement community expects and requires that forensic scientists report the stature of an unidentified body. When the remains are skeletonized or only partially recovered, stature may be estimated from the measurement of long bones, using results of the well-known study of Trotter and Gleser [*1*]. The interest in alternative methods of estimating stature from the skeleton was aroused in one of us (DRJ) when confronted in 1975 by the decomposed, mutilated bodies of two homicide victims within a month of each other, from which the heads, arms and legs had been amputated after death in an apparent attempt to foil identification. The literature at that time contained no clear method for stature estimation from the intact spinal column, so a collection of measurements was begun to remedy this situation. We now report the results of this study, with derivation of regression formulae and comparison between the black and white races and with published Japanese data.

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Materials and Methods

One hundred sixty-seven American white men, 58 American white women, 43 American black men and 31 American black women were selected for our study from over 3000 autopsies performed by one of us (DRJ) over a period of more than 14 years, from January 1978 through September 1993. The cases came from the medical examiner offices in New York City, Suffolk County, New York, Atlantic County, New Jersey and North Carolina. Initially, all autopsied cases of black or white race, at least 18 years of age, from whom injury did not preclude accurate height measurement were selected. The population examined contained relatively few blacks and women; therefore, no further measurements of white men, black men and white women were made after collection of the numbers reported here for each group. Collection of data on black women continued until the end of the study. Table 1 shows the sample sizes, and age ranges, means and standard deviations of the subjects in each of the four study groups.

We made routine measurements of crown-heel lengths of the cadavers, with no correction for postmortem artifact; therefore the results represent cadaver length rather than living stature estimation. The vertebral column was visualized at the end of evisceration, after the neck, chest, abdominal and pelvic organs had been completely removed. The top of the odontoid process could easily be palpated after sharp dissection of the posterior nasopharyngeal tissues from the anterior cervical spine. The cervical, thoracic and lumbar segments were identified, and subjects having abnormal numbers of vertebral segments were not included in the study. We did not exclude individuals showing degenerative aging changes of the spinal column. A flexible ruler graduated in millimeters was laid against the anterior surface of the vertebral bodies along the curve of the spine, and separate measurements were recorded for each of the three segments. The segmental borders were defined at the mid portion of the intervertebral disks as follows:

Cervical: Top of odontoid to between C7 and T1
Thoracic: Between C7 and T1 to between T12 and L1
Lumbar: Between T12 and L1 to between L5 and S1

Since one observer (DRJ) made all measurements, inter observer error did not occur.

Results

The published formulae for estimating stature from the lumbar length of the spine [2] in Japanese males and females were used to calculate stature for each male and female in the current data

TABLE 1—*Numbers and age distributions in groups studied.*

	White Men	White Women	Black Men	Black Women
Number	167	58	43	31
Average Age	47	47	41	36
Minimum Age	18	18	20	18
Maximum Age	86	86	72	81
SD of Age	17	17	15	15

set. A dependent t-test comparing the estimated and known cadaver lengths resulted in a significant difference at the .01 level. In addition, estimates of stature calculated by adding or subtracting the published standard error of estimate for the Japanese regression equations also resulted in significant differences at the .01 level. The inability to apply the published formulae across racial boundaries necessitated the derivation of separate regression formulae for each racial classification.

Table 2 presents the relationship between cadaver length and measured segments of the vertebral column determined from linear regression analysis. Regression equations were derived for white males, white females, black males and black females for each segment of the column, with correlation coefficients ranging from .353 to .823. Sample sizes, sample means, standard deviations, and standard errors of estimate are also reported to facilitate calculation of confidence intervals for single predicted values of stature using the formula presented by Giles and Klepinger [3]. Figurés 1 through 4 are graphs of the thoraco-lumbar segment length versus stature with 95% confidence limits. Figures 5 and 6 present graphs of the lumbar and C-T-L segment length of our data and those of the Japanese [4,2].

Single factor analysis of covariance suggests that, with the exception of the cervical segment, the differences in regression lines for a given segment of the column stem from the differences in the y-intercepts and not differences in slopes. A determination of the sources of variance and the corresponding biological significance is ongoing.

We examined the effect of aging on the spinal segment lengths in the white male series. The other series did not contain sufficient numbers for this analysis. We performed multiple linear regression, using each of the spinal segment lengths and age in years as independent variables, therefore performing five regression analyses. Age contributed significantly at the .05 level only in the lumbar and thoraco-lumbar segments. Table 3 lists the results.

TABLE 2—*Relationship between stature and spinal segment lengths.*

White males (N = 167) Stature[a] = 173.7 ± 8.2 cm

Segment	Segment Length	r	Regression Equation	SE
Cervical	12.963 ± 0.955	.626	$y = 5.399x + 103.707$	6.45
Thoracic	28.894 ± 1.528	.669	$y = 3.603x + 69.606$	5.91
Lumbar	19.253 ± 1.214	.598	$y = 4.058x + 95.562$	6.66
T-L	48.147 ± 2.453	.712	$y = 2.390x + 58.607$	6.03
C-T-L	61.110 ± 3.055	.768	$y = 2.069x + 47.258$	5.29

White females (N = 58) Stature[a] = 162.1 ± 8.0 cm

Segment	Segment Length	r	Regression Equation	SE
Cervical	11.691 ± 0.725	.468	$y = 5.194x + 101.410$	7.11
Thoracic	26.819 ± 1.369	.667	$y = 3.916x + 57.104$	6.08
Lumbar	18.231 ± 0.987	.537	$y = 4.375x + 82.367$	6.87
T-L	45.041 ± 2.097	.690	$y = 2.647x + 42.916$	5.72
C-T-L	56.733 ± 2.482	.720	$y = 2.334x + 29.735$	5.32

Black males (N = 43) Stature[a] = 175.6 ± 8.7 cm

Segment	Segment Length	r	Regression Equation	SE
Cervical	12.705 ± 0.712	.735	$y = 8.922x + 62.262$	5.94
Thoracic	28.574 ± 1.529	.720	$y = 4.071x + 59.289$	6.09
Lumbar	19.144 ± 1.147	.623	$y = 4.696x + 85.723$	6.74
T-L	47.719 ± 2.373	.765	$y = 2.785x + 42.709$	5.82
C-T-L	60.423 ± 2.890	.809	$y = 2.420x + 29.395$	5.09

Black females (N = 31) Stature[a] = 162.9 ± 5.7 cm

Segment	Segment Length	r	Regression Equation	SE
Cervical	11.510 ± 0.804	.353	$y = 2.501x + 134.092$	5.41
Thoracic	26.023 ± 1.540	.819	$y = 3.023x + 84.201$	3.58
Lumbar	18.177 ± 0.994	.686	$y = 3.926x + 91.507$	4.32
T-L	44.200 ± 2.360	.823	$y = 1.984x + 75.208$	2.60
C-T-L	55.710 ± 2.760	.806	$y = 1.661x + 70.336$	3.62

[a]= Mean stature ± standard deviation in centimeters.

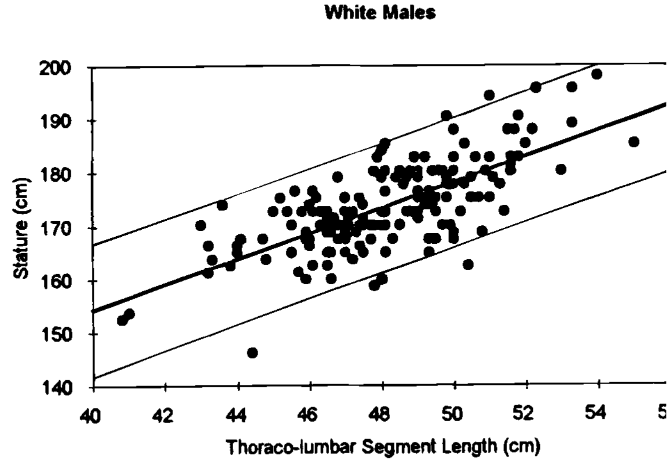

FIG. 1—*Length of the thoraco-lumbar spinal segment versus stature of 167 white males, with regression line and 95% confidence limits.*

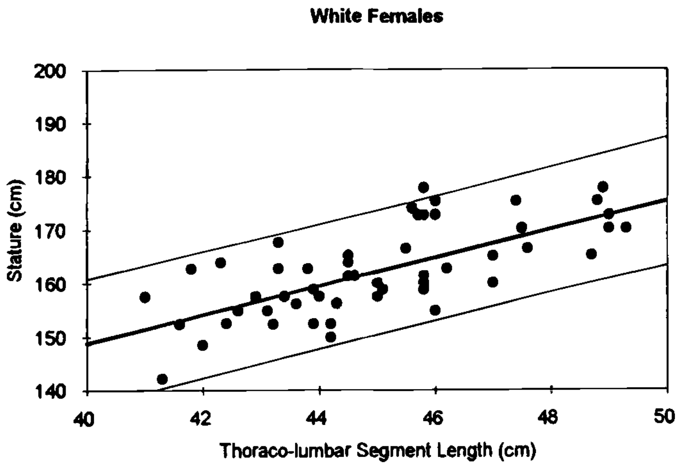

FIG. 2—*Length of the thoraco-lumbar spinal segment versus stature of 58 white females, with regression line and 95% confidence limits.*

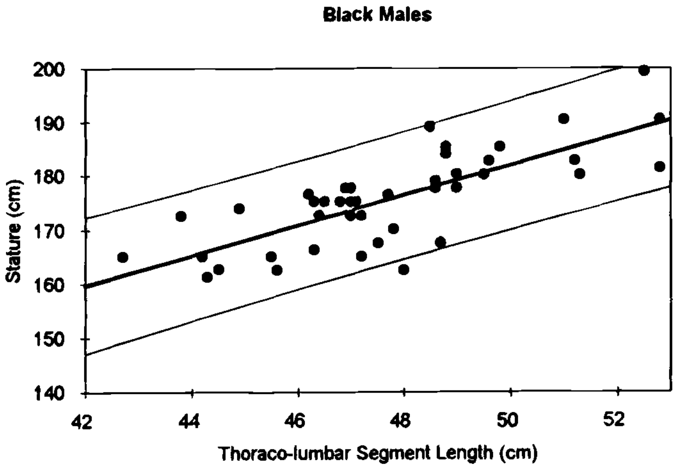

FIG. 3—*Length of the thoraco-lumbar spinal segment versus stature of 43 black males, with regression line and 95% confidence limits.*

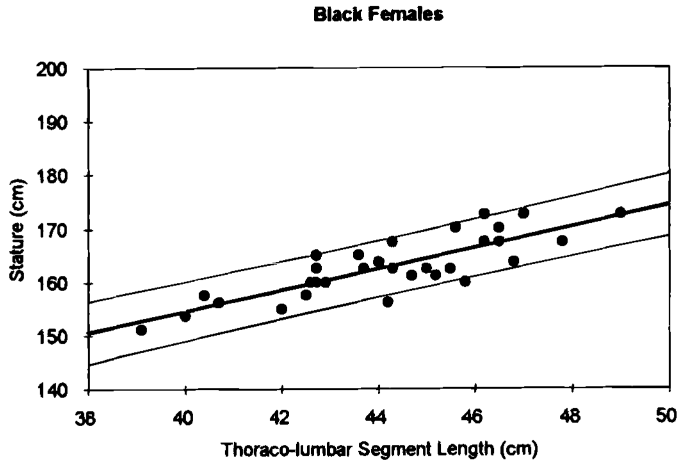

FIG. 4—*Length of the thoraco-lumbar spinal segment versus stature of 31 black females, with regression line and 95% confidence limits.*

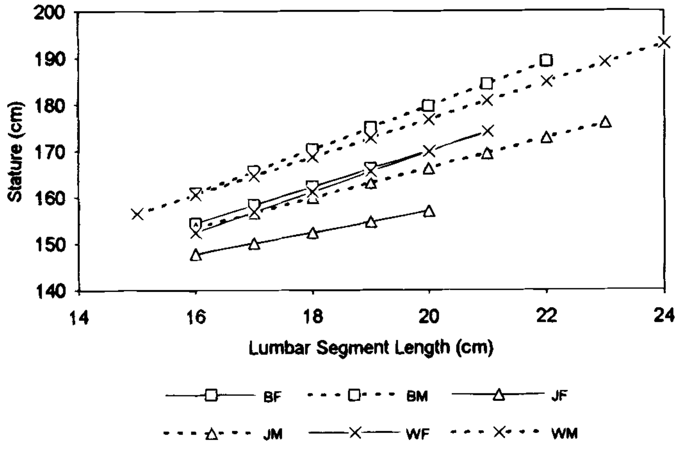

FIG. 5—*Regression lines of the lumbar spinal segments versus statures of black, white, and Japanese males and females. Lines are plotted over the ranges of stature in samples studied.*

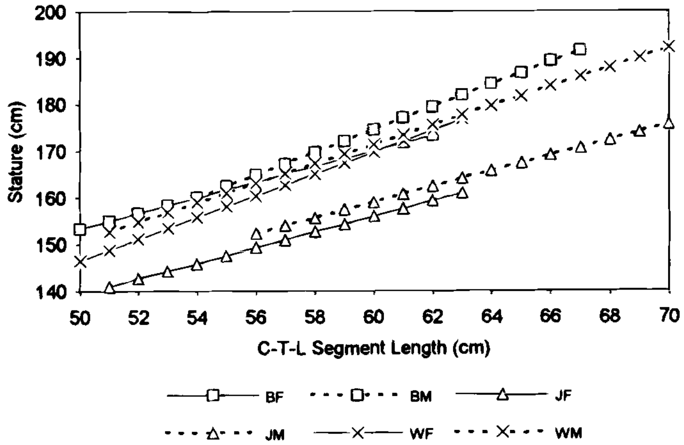

FIG. 6—*Regression lines of the cervico-thoraco-lumbar spinal segments versus statures of black, white, and Japanese males and females. Lines are plotted over the ranges of stature in samples studied.*

Discussion

It is the duty of a medico-legal officer to determine, to the best of his or her ability, the true identity of unidentified remains. One major point of classification is stature. When the body has been mutilated, it is common to have the extremities and/or head amputated from the trunk. An estimate must then be made based on the known relationship of some measurement of the remains to stature. In these cases, the excellent tables relating long bone measurement to height do not help. Our work paralleled that of Terazawa et al. when faced with the same problem at roughly the same period of time [*2,4*]. Our attempts to fit American white and black data to the formulae derived for Japanese was unsuccessful. We therefore developed formulae for estimating stature from various spinal segments of American whites and blacks for use on those populations.

Other than the work of Terazawa et al., the only other published method of estimating stature from spinal length was that of Dwight [*5*]. The method used involved dissection of the spines from the cadavers and measuring a straight line length from the top of the atlas to the sacral promontory. Dwight presented the results as average ratios of the spinal length to stature, after he grouped the spines according to sex and length. Because of the inconvenience and increased labor needed for dissection as well as the error introduced by using average ratios rather than linear regression, the Dwight method is inferior to ours.

Fully and Pineau [*6*] and more recently Tibbetts [*7*], have published methods of estimating stature from the heights of individual vertebrae. The accuracy of their methods is comparable to ours. These methods use dry individual vertebrae, however, and would require not only dissection but defleshing of the spine. When

TABLE 3—*Relationship between stature, spinal segment lengths (x_1) and age[a] (x_2).*

White Males (N = 167)			
Segment	r	Regression Equation	SE
Lumbar	.644	$y = 4.094x_1 - 0.115x_2 + 100.249$	6.34
T-L	.724	$y = 2.331x_1 - 0.064x_2 + 64.428$	5.71

[a]= age at death in years.

dealing with fresh material, our method is therefore more easily applied.

Our multiple regression analysis including age shows that for three of the five segments studied, at least in white males, there is no significant change in the formulae with increasing age. The formulae using lumbar and thoraco-lumbar segments slightly overestimate cadaver length in the elderly. Anterior osteophytosis, mainly in the lumbar region, increasing the distance along the spinal curve best explains this. Since the age estimate of an unknown cadaver is an approximation, introducing more error, there is no practical need to consider it in estimating cadaver length even from those segments.

The availability of these data will be helpful for a variety of reasons:

1. They may be used in a number of circumstances where long bone data are not available. Investigators will benefit by the use of our formulae in cases of intentionally dismembered bodies, fire victims, and partially decomposed remains in which extremities have been removed or severely mutilated by animal scavengers.
2. The T-L segment is likely to be the most useful portion, since intentional dismemberment of the neck usually involves severing the cervical spine, rather than carefully dissecting the atlanto-occipital joint. The standard errors of the estimate for the thoraco-lumbar segments range from 3.28 to 5.87 cm, which is comparable to the data for long bones.
3. Even when long bones are available, but direct measurement of cadaver length cannot be made, dismemberment of the extremities is not necessary to use our method. No additional dissection is needed since evisceration normally involves visualization of the anterior vertebral column, where the measurements are made.

The inability to use the Japanese formulae on our American subjects shows that one must be cautious in extrapolating between different populations. This finding clearly implies the need for more research to develop formulae for other groups, such as Hispanics, rather than assuming that the currently available methods are applicable.

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