TECHNICAL NOTE

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Sacralization of a Sixth Lumbar Vertebra and Its Effect upon the Estimation of Living Stature

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ABSTRACT: Stature is estimated in a case presenting a sacralized sixth lumbar vertebra using both Fully's anatomical method and Trotter and Gleser's stature estimation formulas. In this case, where antemortem stature is known, the accuracy of the anatomical method is enhanced by including the height of the actual S1 segment in the calculation, while the accuracy of the Trotter and Gleser estimate is enhanced by adding the height of the extra vertebra to the stature estimate.

KEYWORDS: physical anthropology, human identification, musculoskeletal system, stature determination

The use of Fully's [*1,2*] anatomical method to estimate living stature from skeletal remains prescribes the measurement of cranial height, the maximum anterior heights of the vertebrae C2 through S1, the bicondylar/physiological lengths of the femur and tibia, and the articulated height of the talus and calcaneus. These measurements are then added together to obtain a skeletal height to which is added a correction factor for the soft tissues. Fully's method and its application have been described in detail by Stewart [*3*] and Lundy [*4-6*].

Since a major component of the skeletal height is spinal length C2 through S1, missing or extra vertebrae can influence stature estimates using the anatomical method. Fully and Pineau [*2*] and Lundy [*7*] have addressed missing presacral vertebrae and the use of the anatomical method. To date, however, the problem of variation in sacral segment number and its possible effect on stature estimation have not been addressed.

This paper discusses possible effects upon stature estimates of a sacralized sixth lumbar vertebra when both the anatomical method described above and standard equations are used to estimate stature.

Materials and Methods

The example case is that of a Negro U.S. Navy aviation officer, shot down during the Vietnam War, whose remains were returned by the Socialist Republic of Vietnam and subse-

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quently identified on the basis of dental records. The skeletal remains are sufficiently complete to utilize Fully's anatomical method to estimate living stature. An accurate record of antemortem height is listed on the subject's Anthropometric Form, which contains detailed measurements required of all naval aviators and flight officers [*8*].

Examination of the remains reveals a congenitally sacralized sixth lumbar vertebra with S1 in the position of second sacral segment (Fig. 1). Stature is estimated using both the anatomical method and Trotter and Gleser's [*9, 10*] formulas.

Results

Table 1 lists values for the measurements taken and the resulting estimated living stature. Table 2 presents a comparison of the results obtained using the anatomical method, both with and without the height of S1, using Trotter and Gleser's [*9, 10*] formula for American Negro males (femur + tibia) with and without the height of L6 added, and the recorded antemortem stature.

Table 2 shows that the anatomical method stature estimate without the height of S1 differs from the recorded stature by 1.26 in. (3.2 cm), while the estimated stature including the height of S1 is identical to the recorded antemortem stature for the individual. The estimate based upon Trotter and Gleser's formula provides a central tendency differing from the recorded stature by 1.10 in. (2.79 cm), but within the estimated range of the equation ($\pm$1.39 in.) [3.53 cm]. As Table 2 shows, this estimate can be improved by adding the height of L6 to it.

Discussion

Bornstein and Peterson [*11*] reported an incidence of L6 in American Negro males of 1.21%, but offered no frequencies for congenitally sacralized sixth lumbar vertebrae.

When the anatomical method is used, the question to be answered when one is confronted with a sacralized lumbar vertebra is whether or not to include the height of the actual S1 in the calculations. In this case the antemortem stature is known, allowing estimated stature to be calculated with and without the height of S1. Comparing both of the estimates with recorded living height suggests that the height of S1 should be included in the calculations.

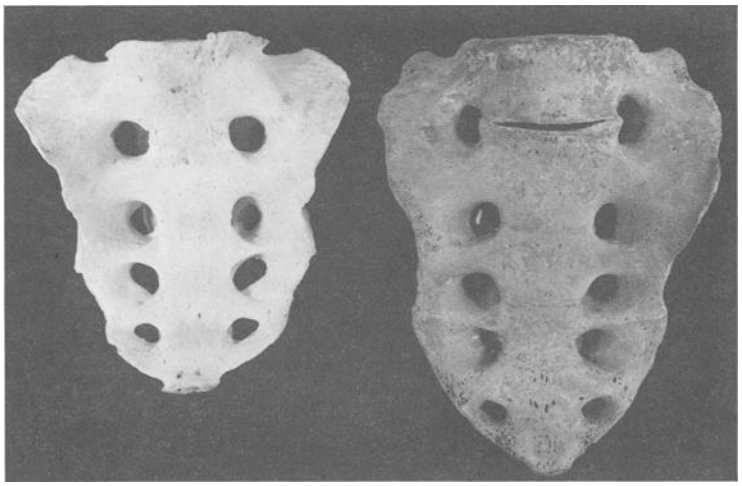

FIG. 1—*Ventral view of a normal sacrum* (left) *and the sacralized L6 sacrum* (right).

TABLE 1—*Measurements for the anatomical method and stature estimate.*

Basi-bregmatic height	137.0 mm
Combined heights C2-L6	515.7 mm
Height of S1	32.0 mm
Length of femur	516.0 mm
Length of tibia	426.5 mm
Talocalcaneal height	84.0 mm
Skeletal height	171.12 cm
Soft tissue correction	11.5 cm[a]
Estimated stature	182.62 cm (71.9 in.)

[a]For skeletal heights of 153.5 cm and less, add 10.0 cm.
For skeletal heights of 153.6 to 165.5 cm, add 10.5 cm.
For skeletal heights above 165.5 cm, add 11.5 cm.

However, in forensic science cases one must provide a stature estimate from unknown remains, without the luxury of knowing the person's living height. When one is confronted with a sacralized L6, articulating the pelvis may provide a clue as to whether to include the height of the actual S1 in the estimate or not. View the pelvis from the front with the long axis of the pubic symphysis perpendicular to the line of vision. Tilting the pelvis into approximate anatomical position seems the best way to determine the relationship between the S1-S2 junction and the superior margin of the acetabulum. In the normal pelvis, the S1-S2 junction lies considerably above the superior margin of the acetabulum. If, in the unknown pelvis, both the sixth lumbar and the actual S1 segments lie above the superior margin of the acetabulum, then the height of S1 should be included in the calculations. If not, then one probably should not include the height of S1.

As has been discussed in previous works [*5,6*], since Trotter and Gleser's equations represent long-bone lengths mathematically regressed against recorded living stature, they do not reflect variations in vertebral number or individual skeletal proportions. It is not surprising to find that using their formulas for American black males (femur + tibia) in this case provides a central tendency of the estimate 1.10 in. (2.79 cm) below recorded stature, although this is still within the range of one standard error of the equation (1.39 in.) [3.53 cm]. In cases presenting a sacralized lumbar vertebra where Trotter and Gleser's or similar stature estimation formulas are used, adding the height of the extra vertebra might enhance the accuracy of the stature estimate.

TABLE 2—*Postmortem stature estimates and antemortem recorded stature.*

Trotter and Gleser Estimate (Femur + Tibia)	Anatomical Method Estimate	Recorded Antemortem Stature[a]
179.8 cm (±3.53 cm) (70.8 in. [±1.39 in.])	179.4 cm[b] (70.64 in.)	182.6 cm (71.9 in.)
182.7 cm (±3.53 cm)[c] (71.94 in. [±1.39 in.])	182.6 cm[d] (71.9 in.)	... ...

[a]From U.S. Navy Anthropometric Form.
[b]Without height of S1.
[c]Estimated stature with height of L6 added.
[d]With height of S1.

In this case, the estimated stature using the Trotter and Gleser equation is 70.8 in. (179.8 cm) with a range of ± 1.39 in. (3.53 cm). If one adds the height of the L6 (29.0 mm) to the central tendency, the resulting estimate is now 71.94 in. (182.73 cm)—much closer to the recorded stature.

Conclusions

When using the anatomical method in cases of sacralized lumbar vertebra, if possible, check the relationship of the S1 to the upper margin of the acetabulum to determine if S1 should be included in the calculations. If the innominates are missing, I suggest estimating height with and without S1 and giving the two results as a range.

If one is using Trotter and Gleser's formulae in a case of sacralized lumbar vertebra, more accuracy might be obtained by adding the height of the extra lumbar vertebra to the stature estimate.

A couple of caveats are in order. First, both the anatomical and mathematical methods provide us with an estimate of living stature—neither method is designed, nor should be expected to provide a person's precise antemortem stature. Second, this example is only one case involving a sacralized sixth lumbar vertebra. At best, it points toward the need for more study of the topic, and the results must not be interpreted as generalizations. We must learn far more about the variability of sacralized sixth lumbar vertebrae before general statements as to its relationship to stature can be made. This paper offers one approach to estimating stature when confronted with the rare situation of a sacralized sixth lumbar vertebra.

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References

[1] Fully, G., "Une Nouvelle Methode de Determination de la Taille," *Annals de Medecine Legale*, Vol. 35, No. 5, 1956, pp. 266–273.

[2] Fully, G. and Pineau, H., "Determination de la Stature au Moyen du Squelette," *Annals de Medecine Legale*, Vol. 40, 1960, pp. 145–154.

[3] Stewart, T. D., *Essentials of Forensic Anthropology: Especially as Developed in the United States*, Charles C Thomas, Springfield, IL, 1979.

[4] Lundy, J. K., "Regression Equations for Estimating Living Stature from Long Limb Bones in the South African Negro," *South African Journal of Science*, Vol. 79, No. 8, Aug. 1983, pp. 337–338.

[5] Lundy, J. K., "The Mathematical Versus Anatomical Methods of Stature Estimate from Long Bones," *American Journal of Forensic Medicine and Pathology*, Vol. 6, No. 1, March 1985, pp. 73–76.

[6] Lundy, J. K., "A Report on the Use of Fully's Anatomical Method to Estimate Stature in Military Skeletal Remains," *Journal of Forensic Sciences*, Vol. 33, No. 2, March 1988, pp. 534–539.

[7] Lundy, J. K., "A Note on Missing Presacral Vertebrae and the Use of Fully's Anatomical Method to Estimate Living Stature in the South African Negro," *South African Journal of Science*, Vol. 81, Jan. 1985, p. 42.

[8] "Anthropometric Limitation in Naval Aircraft," Naval Training Instruction No. 13520.1, U.S. Navy, 1980.

[9] Trotter, M. and Gleser, G., "Re-evaluation of Stature Based on Measurements Taken During Life and of Long Bones After Death," *American Journal of Physical Anthropology*, Vol. 16, No. 1, Jan. 1958, pp. 79–123.

[10] Trotter, M., "Estimation of Stature from Intact Long Limb Bones" in *Personal Identification in Mass Disasters*, T. D. Stewart, Ed., National Museum of Natural History, Washington, DC, 1970, pp. 71–83.

[11] Bornstein, P. E. and Peterson, R. R., "Numerical Variation of the Presacral Vertebral Column in Three Population Groups in North America," *American Journal of Physical Anthropology,* Vol. 25, No. 2, Sept. 1966, pp. 139–146.

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