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# Individuation in Forensic Science Study: Decapitation

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**ABSTRACT:** In this study we present a technique that may be useful in the individuation of remains separated through the cervical region. Using a series of measurements from young female skeletons in the Terry Collection, we have developed a model for testing congruence between adjacent elements. Emphasis has been placed on identifying those measurements most likely to minimize underestimating the true number of remains present. The use of the technique has been demonstrated in two (retrospective) forensic science examples.

**KEY WORDS:** physical anthropology, musculoskeletal system, human identification, human osteology

Individuation is a problem frequently faced by the forensic anthropologist. Body parts may become dispersed in mass disasters, as a result of fortuitous postmortem events, or by criminal intent. In any of these circumstances, the forensic anthropologist is likely to be called upon to present arguments concerning minimum numbers of individuals and the association of elements that may reflect the remains of a single person.

Anthropologists have responded to the challenge of individuation with varied strategies. Krogman's text [*1*] contains a chapter on individuation that emphasizes such topics as postmortem alterations because of bone desiccation, age/sex differences in the rib and sternum, and bone density. Snow and co-workers [*2,3*] have published a technique for estimating the probability that only one individual is present when dispersed elements are discovered. Individualized patterns of fluorescence have also been investigated [*4,5*], as have direct tests of chemical composition [*6,7*]. However, as exemplified in the often-cited Ruxton case [*8*], a most convincing line of evidence, when available, is perhaps the most obvious: the degree of congruence between joint surfaces.

Biomedical scientists have presented the most detailed studies of joint congruence, usually as an aspect of arthritis research and frequently emphasizing joints of the lower limb. Greenwold's extensive investigation of degenerative joint disease in association with congruence of the hip joint [*9*] is a good example. Though anthropologists have collected reams of data concerning bone length and shape variation in osseous structures, most of these data are presented as averages across populations or population samples, and they seldom approach the topic of joint congruence from the perspective of intra-individual patterning or inter-individual variability. The forensic scientist faced with the need to develop a probability estimate based on such data will not likely find published reports

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suitable for his particular problem and may therefore be forced to discuss, as did the scholars in the Ruxton case, observations of "harmony" between adjacent joint surfaces.

Stimulated by both forensic and archaeological examples, we have become interested in a specialized aspect of individuation: decapitation. It is our impression that sufficient situations of questionable compatibility between cervically disassociated cranial and post-cranial remains exist to make this a worthwhile research problem. The senior author has been consulted in one case of this type, and extensive comparative data could have been persuasive in the Ruxton example. In this investigation we leave aside questions of cut marks and other artifacts of the decapitation process. We are primarily concerned with variation in the morphology of adjacent structures extending from the atlanto-occipital region to the seventh cervical vertebrae. Choice of study sample and analytical techniques were influenced both by the authors' recent experience and by the Ruxton case. These forensic science examples also stimulated our secondary interest in vertebral maturation during late adolescence/young adulthood.

## Materials and Methods

The study sample comprises all Terry Collection skeletons listed as black females between the ages of 16 and 25. There are 33 remains so listed, although on occasion the array of observations is limited by the presence of such conditions as assimilation of the atlas and incomplete neural arches. In no case, however, did the number of observations fall below 32. Two types of data were recorded: measurements and degree of epiphyseal union.

All measurements were taken by the senior author with dial-reading calipers. Taken to the nearest 0.1 mm, each measurement was recorded and later checked. If the second measurement was within $\pm 0.1$ mm of the original, then the original observation was retained. Scores of $\pm 0.2$ mm were averaged, and broader deviations required a third measurement, which in all cases was within $\pm 0.2$ mm of one of the prior observations. In such situations, the two closer measurements were then treated as if they were the first pair.

An initial survey of observations commonly taken of the region in question disclosed that most had been made in the course of studies of sexual dimorphism [*10-13*] or as an aspect of population variability [*14-21*]. The most common measure is that of vertebral body height, which has been most extensively documented in reference to population description or age changes in the lumbar region [*22-25*]. Body height measurements have also been taken in studies of changes in the vertebral column during maceration [*26*], and comparability of radiographic and direct measurement techniques has been investigated [*27*]. Because our investigation was somewhat different from previous work we decided to generate a new set of measurements, relying whenever possible on previously defined standards. Measurement pairs that most likely would reflect congruence between adjacent elements were selected. These are defined in Table 1 and illustrated in Figs. 1 to 4.

For each paired set of measurements, for example, OP and C1P, a new variable (OC1P) was generated by subtracting the measurement for the more caudal (inferior) element from that of the more cranial (superior) unit. In the case of OP and C1P, the new variable OC1P would reflect the result if C1P were subtracted from OP. To isolate those new variables that denoted close congruence between adjacent elements, measures of dispersion and central tendency were generated for the absolute values of the variables by using the program CONDESCRIPTIVE from the Statistical Package for the Social Sciences [*29*].

Table 2 defines and Figure 5 illustrates the stages of epiphyseal ring fusion recorded in this study. As indicated by McKern and Stewart [*30*], there is little information available concerning the timing of fusion for these secondary ossification centers with the centra. McKern and Stewart [*30*] provide ossification data for the thoracic region in a racially

TABLE 1—*Definition of measurements.*

| Element | Symbol and Definition[a] | Observation Pairing and Variable Definition |
|---|---|---|
| 1. occipital | OAM: distance between the most anterior-medial points of the occipital condyles, coronal plane | *OAM* − C1AM = OC1AM |
| 2. occipital | OAL: distance between the most lateral points on the anterior half of the occipital condyles, coronal plane | *OAL* − C1AL = OC1AL |
| 3. occipital | OP: distance between the most posterior points on the occipital condyles, coronal plane | *OP* − C1OP = OC1P |
| 4. occipital | OMAP: maximum internal diameter of foramen magnum, sagittal plane, that is, from basion to opisthion, as defined by Hrdlička [*28*, p. 21] | *OMAP* − OC1AP = OC1MAP |
| 5. 1st cervical vertebra | C1AM: distance between the most anterior-medial points of the superior articular facets, coronal plane | OAM − *C1AM* = OC1AM |
| 6. 1st cervical vertebra | C1AL: distance between the most lateral points on the anterior half of the superior articular facets, coronal plane | OAL − *C1AL* = OC1AL |
| 7. 1st cervical vertebra | CIP: distance between the most posterior points on the superior articular facets, coronal plane | OP − *C1P* = OC1AP |
| 8. 1st cervical vertebra | C1MAP: maximum internal diameter of the vertebral canal, sagittal plane, corresponding to the measurement referenced by Hrdlička [*17*, p. 365], Dubreuil-Chambardel [*13*, p. 400], and Hasebe [*14*, p. 306, #5] | OMAP − *C1MAP* = OC1AP |
| 9. 1st cervical vertebra | C1IL: distance between the most lateral points on the inferior articular facets, coronal plane, corresponding to #8 of Hasebe [*14*] | *C1IL* − C2SL = C12L |
| 10. 1st cervical vertebra | C1IM: distance between the most medial points on the inferior articular facets, coronal plane | *C1IM* − C2SM = C12M |
| 11. 2nd cervical vertebra | C2SL: distance between the most lateral points on the superior articular facets, coronal plane, corresponding to the measurement #9 of Helmuth and Rempe [*12*, p. 302]; Hasebe [*14*] also reports this measurement | C1IL − *C2SL* = C12L |
| 12. 2nd cervical vertebra | C2SM: distance between the most medial points on the superior articular facets, coronal plane | C1IM − *C2SM* = C12M |

| | | |
|---|---|---|
| 13. 2nd cervical vertebra[b] | C2IAP: maximum anterior-posterior distance of the inferior surface of the body, including the epiphyseal ring (when present), sagittal plane | *C2IAP* – C3SAP = C23AP |
| 14. 2nd cervical vertebra[b] | C2IMLMIN: on the inferior surface, the maximum distance between the inflection points at the lateral aspect of the horizontal surface of the body as this surface meets the articular surface for the lips of the adjacent vertebra, coronal plane | *C2IMLMIN* – C3SMLMIN = C23MLMIN |
| 15. 2nd cervical vertebra[b] | C2IMLMAX: on the inferior surface, the maximum distance between the most inferior-lateral points of the articular facets for the lips of the adjacent vertebra, coronal plane | *C2IMLMAX* – C3SMLMAX = C23MLMAX |
| 16. 2nd cervical vertebra[b] | C2IZMIN: distance between the most medial points on the postzygapophyses, coronal plane, perhaps corresponding to the measurement described by the researchers in the Ruxton case [*8*, p. 49]; Helmuth and Rempe [*12*] and Hasebe [*14*] also report this measurement | *C2IZMIN* – C3SZMIN = C23ZMIN |
| 17. 2nd cervical vertebra[b] | C2IZMAX: distance between the most lateral points on the postzygapophyses, coronal plane, perhaps corresponding to the measurement described by the researchers in the Ruxton case [*8*, p. 49] | *C2IZMAX* – C3SZMAX = C23ZMAX |
| 18. 3rd cervical vertebra[c] | C3SAP: maximum anterior-posterior distance of the superior surface of the body, including the epiphyseal ring (when present), sagittal plane | C2IAP – *C3SAP* = C23AP |
| 19. 3rd cervical vertebra[c] | C3SMLMIN: on the superior surface, the maximum distance between the inflection points at the base of the lips as they meet the horizontal surface of the body, coronal plane | C2IMLMIN – *C3SMLMIN* = C23MLMIN |
| 20. 3rd cervical vertebra[c] | C3SMLMAX: on the superior surface, the maximum distance between the most lateral points on the articular surface at the superior aspect of the lips, coronal plane | C2IMLMAX – *C3SMLMAX* = C23MLMAX |
| 21. 3rd cervical vertebra[c] | C3SZMIN: distance between the most medial points on the prezygapophyses, coronal plane | C2IZMIN – *C3SZMIN* = C23ZMIN |
| 22. 3rd cervical vertebra[c] | C3SZMAX: distance between the most lateral points on the prezygapophyses, coronal plane, perhaps corresponding to the measurement described by researchers in the Ruxton case [*8*, p. 49] | C2IZMAX – *C3SZMAX* = C23ZMAX |

[a] All nonpathological extensions of articular facets are included; arthritic structures and ligamentous/tendinous ossifications are not.
[b] These definitions are repeated for the 3rd, 4th, 5th, and 6th cervical vertebrae.
[c] These definitions are repeated for the 4th, 5th, 6th, and 7th cervical vertebrae.

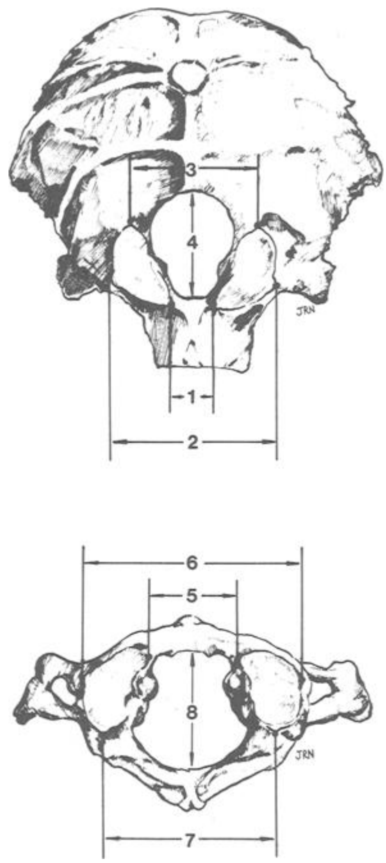


FIG. 1—*Measurements 1 through 8.*

mixed sample of males between the ages of 17 and 25. The present study reports ossification patterns for the cervical region in black females of comparable age. Observations were recorded separately for the superior and inferior surfaces of each vertebral unit as well as for the dorsal (posterior) and ventral (anterior) halves of each element. It should be noted that the recorded cause of death for these females frequently included disease states that could have slowed maturation processes, and we therefore believe that our data are best used as a maximum estimate for developmental timing in a population not under similar disease stress. Our results concerning the pattern of fusion should, however, be representative. It is important to note that an effort was made to replicate the McKern and Stewart scoring technique. It appears, however, that only the initial two or three stages are comparable (0, 1, 2). For this reason, our data should not be directly compared with data collected through the use of the McKern and Stewart standards.

In statistical evaluation of the ossification sequences, the program FREQUENCIES [*29*] was used for developing descriptive statistics and the program NPAR [*31*] for generating the Wilcoxon matched-pairs signed-ranks test. The Wilcoxon statistic tested a series of hypotheses designed to isolate consistent differences in ossification timing between superior and inferior surfaces of each vertebral body and between dorsal and ventral halves of every surface.

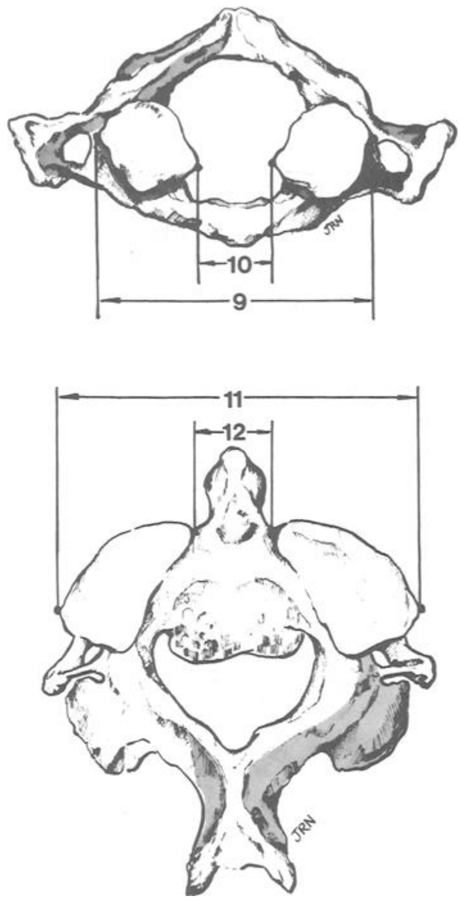


FIG. 2—*Measurements 9 through 12.*

**Results and Discussion**

Table 3 presents descriptive statistics for the measurements defined in the previous section. We believe that those measurements with the smallest dispersions, that is, those with the lowest values for standard deviation and the smallest 0.95 confidence interval, will be those most likely to minimize Type II error, which, in this study, would be the merging of remains from two individuals.

To facilitate identification of those measures with the least dispersion, we have in Table 4 grouped confidence interval sizes by 0.05-mm increments, with the values at the higher end of the scale being summarized in larger units. From Table 4 it is clear that confidence interval sizes tend to vary by parameter rather than by anatomical location. In other words, AP confidence intervals tend to be smaller than those for MLMAX across all vertebrae. An exception to this generalization is those measures for the atlanto-occipital articulation; these confidence intervals tend to be relatively large. According to Table 4, the measurements of closest congruence are AP, C12L, 2MAX, and ZMIN followed by MLMIN and C12M. With few exceptions, the values for MLMAX are larger than the other cervical parameters, with those characterizing the region around the foramen magnum being largest. Although it is possible that the variables with relatively large

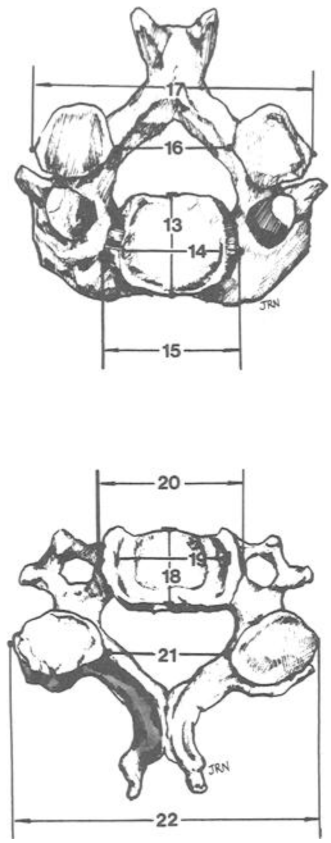


FIG. 3—*Measurements 13 through 22.*

confidence intervals will become useful in certain circumstances, it seems likely that those with least dispersion, such as AP and C12L, will be those of greatest utility in forensic science work.

Table 5 presents summary data, grouped by age, for epiphyseal ring fusion within the cervical region. In a general sense, it is clear that the anatomy books are correct: by age 25 the epiphyseal rings are fused to the centra. It is also obvious that, at any given age, the more cranially directed cervical vertebrae tend to be at a stage of maturation more advanced than that of the more caudal units. Subtler is the possible existence of consistent variations within vertebrae, either by surface (superior versus inferior) or by aspect of single epiphyses (dorsal versus ventral), which could become important in forensic science study. To isolate such systematic differences in maturation, we have compared for each vertebra the stage of epiphyseal union by aspect and by surface. Table 6 summarizes probability estimates for these comparisons, given the null hypothesis that there exist no significant differences between surfaces or within aspects of the same epiphysis. As indicated in the previous section, the Wilcoxon matched-pairs signed-ranks test was used in this evaluation.

In only two cases did there appear to be a significant difference in maturational stages between dorsal and ventral aspects of the same epiphysis. On the inferior surfaces of both C4 and C6, the dorsal aspect was significantly more advanced than the ventral. The surface comparisons, however, provided clear indications that at least on the ventral

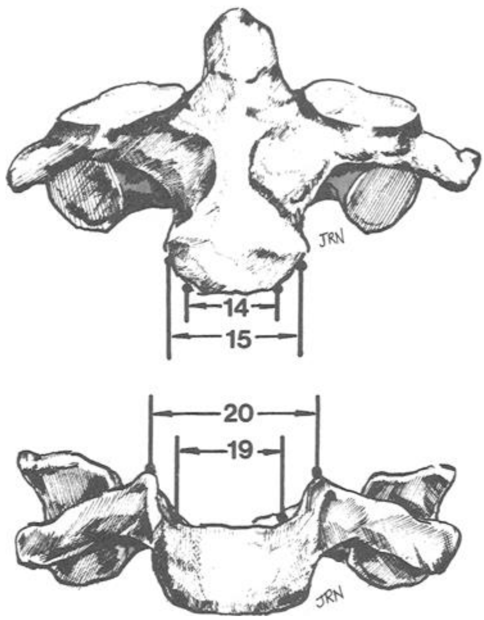


FIG. 4—*Alternate view of Measurements 14, 15, 19, and 20.*

TABLE 2—*Definition of stages of epiphyseal ring fusion.*

| Stage | Definition |
|---|---|
| 0 | unfused, ring absent |
| 1 | ring present and partially fused; unfused sections evident |
| 2 | ring completely fused; edges of ring clearly defined throughout circumference |
| 3 | ring completely fused; edges of ring indistinct, that is, integrated with centrum, in a portion of the circumference |
| 4 | ring completely fused; edges of ring integrated with centrum throughout circumference |

aspect the superior surface was consistently more advanced than the inferior for each vertebral body. Probability values for the ventral aspects of all vertebrae are less than 0.05; and in the case of two dorsal aspects, C3 and C5, the probability levels are between 0.05 and 0.1. Thus, although McKern and Stewart [*30*, p. 99] report no significant differences in rate of epiphyseal ring fusion between surfaces of thoracic vertebrae in their racially mixed samples of males, such is not the case for the cervical units reported here, particularly the ventral aspect of the epiphysis. True locational differences in maturational pattern or the effects of age, sex, or health status on epiphyseal union may be reflected in these rates. Differences in observational technique and analytical procedures also may have affected the results of the two studies.

## Examples

We will illustrate forensic science application of our research results with two retrospective examples: the first is drawn from the files of the senior author, and the second is the Ruxton case [*8*]. Table 7 summarizes relevant observations for these two cases as well as means and standard deviations computed for the Terry Collection sample. In addition,

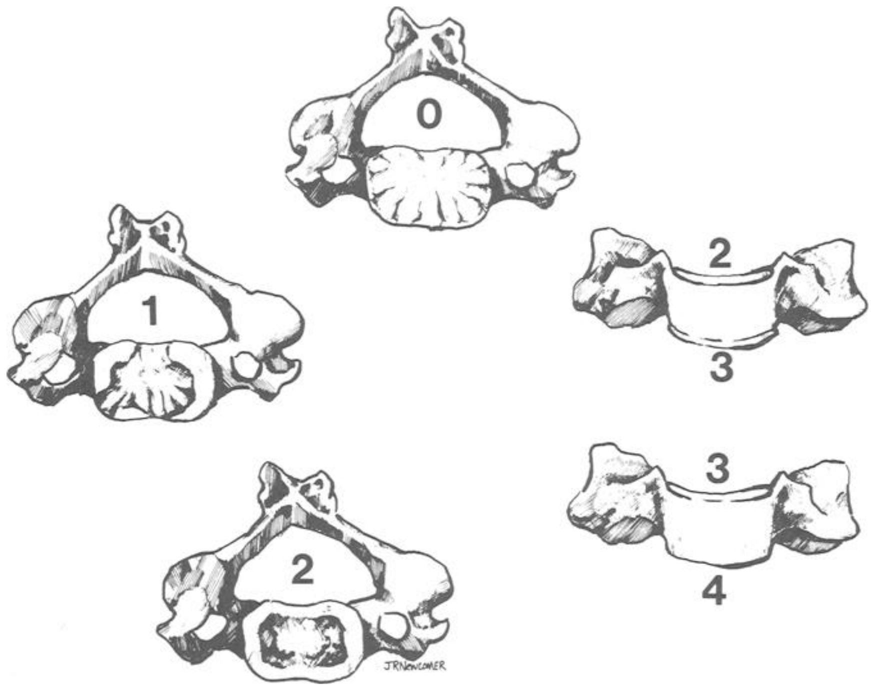


FIG. 5—*Stages of epiphyseal ring fusion.*

a probability estimate has been calculated, testing the null hypothesis that the observed values do not differ significantly from the Terry Collection means [*31*]. The $t$ statistic was computed by hand with the data presented in Table 3. A two-tailed test was used.

*Case 1*

In this example, a determination of probable congruence between a third and a fourth cervical vertebra was requested. The third was the last in a series of three units that had been found in the defendant's possession. It was alleged that these, along with the skull, had been removed from the body of a young adult black female. Three of the five measurements reported in the present study, AP, MLMAX, and MLMIN, were recorded by the senior author. Although the evidence was viewed two years prior to the Terry Collection research, data collection techniques should be comparable.

As can be seen in Table 7, values for two of the three variables differ significantly from the Terry Collection means. Importantly, as indicated in Tables 3 and 4, these two parameters are of relatively small dispersion when compared to MLMAX, the variable for which the difference is not significant. Given that two of the three variables show significant differences and that the single parameter that does not had been designated a priori as a poor discriminator, the null hypothesis can be rejected with confidence. Because there is minimal congruence between the third and fourth cervical elements, the remains viewed as evidence are therefore inferred to include at least two individuals.

*Case 2*

In the Ruxton case, Glaister and Brash [*8*] were concerned with the "fit" between a trunk segment including the last two cervical vertebrae, the thorax, and two lumbar

TABLE 3—*Summary statistics for derived variables (in mm).*

| Variable Name | Mean | Min/Max | Standard Deviation | 0.95 Confidence Interval | Confidence Interval Size |
|---|---|---|---|---|---|
| OC1AM | 1.88 | 0.0/75.0 | 1.59 | 1.31 to 2.44 | 1.13 |
| OC1AL | 1.90 | 0.0/54.0 | 1.55 | 1.35 to 2.45 | 1.10 |
| OC1P | 2.85 | 0.0/77.0 | 2.13 | 2.10 to 3.61 | 1.51 |
| OC1MAP[a] | 5.98 | 20.0/99.0 | 2.24 | 5.17 to 6.78 | 1.61 |
| C12L | 0.42 | 0.0/12.0 | 3.61 | 0.30 to 0.55 | 0.25 |
| C12M | 1.52 | 1.0/34.0 | 0.90 | 1.20 to 1.84 | 0.64 |
| C23AP | 0.71 | 1.0/17.0 | 0.47 | 0.54 to 0.88 | 0.34 |
| C34AP | 0.65 | 0.0/18.0 | 0.51 | 0.47 to 0.83 | 0.36 |
| C45AP | 0.79 | 1.0/18.0 | 0.45 | 0.63 to 0.95 | 0.32 |
| C56AP[a] | 0.59 | 0.0/12.0 | 0.41 | 0.44 to 0.73 | 0.29 |
| C67AP | 0.41 | 0.0/10.0 | 0.31 | 0.30 to 0.52 | 0.22 |
| C23MLMIN | 0.81 | 1.0/18.0 | 0.57 | 0.61 to 1.01 | 0.40 |
| C34MLMIN | 0.64 | 0.0/30.0 | 0.66 | 0.40 to 0.87 | 0.47 |
| C45MLMIN | 0.85 | 1.0/26.0 | 0.60 | 0.63 to 1.06 | 0.43 |
| C56MLMIN[a] | 0.92 | 1.0/24.0 | 0.58 | 0.71 to 1.13 | 0.42 |
| C67MLMIN | 1.22 | 1.0/29.0 | 0.77 | 0.95 to 1.49 | 0.54 |
| C23MLMAX | 1.92 | 1.0/59.0 | 1.32 | 1.45 to 2.39 | 0.94 |
| C34MLMAX | 1.73 | 3.0/44.0 | 1.04 | 1.36 to 2.09 | 0.73 |
| C45MLMAX | 1.89 | 0.0/59.0 | 1.09 | 1.50 to 2.27 | 0.77 |
| C56MLMAX[a] | 2.26 | 1.0/34.0 | 0.77 | 1.98 to 2.53 | 0.55 |
| C67MLMAX | 2.50 | 4.0/41.0 | 0.94 | 2.17 to 2.83 | 0.66 |
| C23ZMIN | 0.58 | 0.0/15.0 | 0.46 | 0.41 to 0.74 | 0.33 |
| C34ZMIN | 0.66 | 1.0/15.0 | 0.42 | 0.51 to 0.81 | 0.30 |
| C45ZMIN | 0.61 | 0.0/17.0 | 0.43 | 0.46 to 0.76 | 0.30 |
| C56ZMIN[a] | 0.76 | 0.0/29.0 | 0.63 | 0.53 to 0.98 | 0.45 |
| C67ZMIN | 0.76 | 1.0/20.0 | 0.51 | 0.58 to 0.95 | 0.37 |
| C23ZMAX | 0.57 | 1.0/15.0 | 0.36 | 0.44 to 0.69 | 0.25 |
| C34ZMAX | 0.50 | 0.0/16.0 | 0.41 | 0.35 to 0.65 | 0.30 |
| C45ZMAX | 0.64 | 0.0/23.0 | 0.51 | 0.46 to 0.82 | 0.36 |
| C56ZMAX[a] | 0.69 | 1.0/15.0 | 0.36 | 0.56 to 0.82 | 0.26 |
| C67ZMAX | 0.54 | 0.0/14.0 | 0.39 | 0.40 to 0.68 | 0.28 |

[a] For these variables $n = 32$. In all other cases $n = 33$.

TABLE 4—*Summary table of 0.95 confidence interval sizes.*

| Interval Size | Variables |
|---|---|
| 0.20–0.24 | C67AP |
| 0.25–0.29 | C12L, C56AP, C23ZMAX, C56ZMAX, C67ZMAX |
| 0.30–0.34 | C23AP, C45AP, C34ZMAX, C23ZMIN, C34ZMIN, C45ZMIN |
| 0.35–0.39 | C34AP, C45ZMAX, C67ZMIN |
| 0.40–0.44 | C23MLMIN, C45MLMIN, C56MLMIN |
| 0.45–0.49 | C56ZMIN, C34MLMIN |
| 0.50–0.59 | C67ZMIN, C56MLMAX |
| 0.60–0.69 | C12M, C67MLMAX |
| 0.70–0.79 | C34MLMAX, C45MLMAX |
| 0.80–0.89 | . . . |
| 0.90–0.99 | C23MLMAX |
| 1.00–1.49 | OC1AM, OC1AL |
| 1.50+ | OC1P, OC1MAP |

TABLE 5—*Stages of epiphyseal ring fusion in cervical vertebrae (Terry Collection black females, ages 17 to 25 years).*

| Vertebral Surface[a] | Stages of Fusion by Age[b] | | | | | |
|---|---|---|---|---|---|---|
| | 17-19 | 20-21 | 22 | 23 | 24 | 25 |
| C2ID | 2(2/5) 3(3/5) | 3(3/4) 4(1/4) | 2(1/5) 3(4/5) | 3(5/5) | 3(7/7) | 3(5/6) 4(1/6) |
| C2IV | 3(3/4) 4(1/4) | 2(1/4) 3(3/4) | 2(1/4) 3(3/4) | 3(5/5) | 3(6/7) 4(1/7) | 3(3/6) 4(3/6) |
| C3SD | 1(1/5) 3(4/5) | 3(4/4) | 3(5/5) | 3(5/5) | 3(5/7) 4(2/7) | 3(6/6) |
| C3SV | 2(2/5) 3(2/5) 4(1/5) | 2(1/4) 3(3/4) | 3(3/5) 4(2/5) | 3(5/5) | 3(6/7) 4(1/7) | 3(6/6) |
| C3ID | 1(1/5) 2(2/5) 3(2/5) | 3(4/4) | 2(2/5) 3(3/5) | 2(1/5) 3(4/5) | 2(1/7) 3(5/7) 2(1/7) | 3(4/6) 4(2/6) |
| C3IV | 1(1/5) 2(3/5) 3(1/5) | 2(2/4) 3(2/4) | 1(1/5) 2(1/5) 3(3/5) | 2(2/5) 3(3/5) | 3(6/7) 4(1/7) | 3(6/6) |
| C4SD | 1(1/5) 2(1/5) 3(3/5) | 3(4/4) | 1(1/5) 3(4/5) | 3(5/5) | 3(7/7) | 3(6/6) |
| C4SV | 1(1/5) 2(1/5) 3(2/5) 4(1/5) | 2(1/4) 3(3/4) | 2(1/5) 3(4/5) | 3(5/5) | 3(6/7) 4(1/7) | 3(6/6) |
| C4ID | 0(1/5) 2(2/5) 3(2/5) | 3(4/4) | 2(2/5) 3(3/5) | 3(5/5) | 2(1/7) 3(6/7) | 3(6/6) |
| C4IV | 0(1/5) 2(4/5) | 2(4/4) | 1(1/5) 2(3/5) 3(1/5) | 2(2/5) 3(3/5) | 2(1/7) 3(5/7) 4(1/7) | 2(2/6) 3(4/6) |
| C5SD | 0(1/5) 2(2/5) 3(2/5) | 3(4/4) | 3(5/5) | 3(5/5) | 3(7/7) | 3(6/6) |
| C5SV | 1(1/5) 2(1/5) 3(3/5) | 2(1/4) 3(3/4) | 3(4/5) 4(1/5) | 3(4/5) 4(1/5) | 3(6/7) 4(1/7) | 3(6/6) |
| C5ID | 0(1/5) 2(2/5) 3(2/5) | 0(1/4) 2(2/4) 3(1/4) | 2(1/5) 3(4/5) | 3(4/4) | 3(7/7) | 3(6/6) |
| C5IV | 1(2/5) 2(2/5) 3(1/5) | 2(3/4) 3(1/4) | 2(3/5) 3(2/5) | 3(4/4) | 2(2/7) 3(4/7) 4(1/7) | 2(1/6) 3(5/6) |
| C6SD | 0(1/5) 2(2/5) 3(2/5) | 3(4/4) | 3(5/5) | 3(4/4) | 3(7/7) | 2(1/6) 3(5/6) |
| C6SV | 0(1/5) 2(1/5) 3(3/5) | 2(2/4) 3(2/4) | 2(1/5) 3(3/5) 4(1/5) | 3(3/4) 4(1/4) | 3(6/7) 4(1/7) | 3(6/6) |
| C6ID | 1(1/5) 2(3/5) 3(1/5) | 2(2/4) 3(2/4) | 2(3/5) 3(2/5) | 2(2/5) 3(3/5) | 2(1/7) 3(6/7) | 3(6/6) |
| C6IV | 1(1/5) 2(4/5) | 2(3/4) 3(1/4) | 1(1/5) 2(3/5) 3(1/5) | 2(2/5) 3(3/5) | 2(3/7) 3(4/7) | 2(2/6) 3(4/6) |
| C7SD | 0(1/5) 2(4/5) | 2(1/4) 3(3/4) | 2(1/5) 3(4/5) | 3(5/5) | 2(1/7) 3(5/7) 4(1/7) | 2(1/6) 3(5/6) |
| C7SV | 1(1/5) 2(2/5) 3(2/5) | 2(2/4) 3(2/4) | 2(2/5) 3(3/5) | 2(1/5) 3(4/5) | 3(7/7) | 3(6/6) |
| C7ID | 1(2/5) 2(3/5) | 2(2/4) 3(2/4) | 2(2/5) 3(3/5) | 2(2/5) 3(3/5) | 2(1/7) 3(6/7) | 3(6/6) |
| C7IV | 2(5/5) | 2(2/4) 3(2/4) | 2(4/5) 3(1/5) | 2(4/5) 3(1/5) | 2(2/7) 3(5/7) | 2(1/3) 3(2/3) |

[a] I = inferior surface; S = superior surface; D = dorsal aspect; and V = ventral aspect.
[b] Stage (number/total number).

TABLE 6—*Probability estimates for Wilcoxon matched-pairs signed-ranks test.*

| Dorsal Versus Ventral Aspects | | | Superior Versus Inferior Surfaces | | |
|---|---|---|---|---|---|
| Units Compared[a] | $n$ | $P$ of Values Differing by Chance | Units Compared[a] | $n$ | $P$ of Values Differing by Chance |
| C2ID/C2IV | 32 | 0.735 | C3SD/C3ID | 33 | 0.091 |
| C3SD/C3SV | 33 | 0.735 | C3SV/C3IV | 33 | 0.003 |
| C3ID/C3IV | 33 | 0.062 | C4SD/C4ID | 33 | 0.225 |
| C4SD/C4SV | 33 | 0.686 | C4SV/C4IV | 33 | 0.000 |
| C4ID/C4IV | 33 | 0.003 | C5SD/C5ID | 32 | 0.063 |
| C5SD/C5SV | 33 | 0.311 | C5SV/C5IV | 32 | 0.002 |
| C5ID/C5IV | 32 | 0.480 | C6SD/C6ID | 32 | 0.272 |
| C6SD/C6SV | 32 | 0.529 | C6SV/C6IV | 32 | 0.001 |
| C6ID/C6IV | 33 | 0.044 | C7SD/C7ID | 33 | 0.208 |
| C7SD/C7SV | 33 | 1.000 | C7SV/C7IV | 33 | 0.007 |

[a] S = superior; I = inferior; D = dorsal; and V = ventral.

TABLE 7—*Comparison of forensic science data with Terry Collection parameters.*

| Case | Variable | Value | Terry Mean ($n$) | Terry Standard Deviation | $t$ | $P$ |
|---|---|---|---|---|---|---|
| 1 | C34AP | 3.6 | 0.65 (33) | 0.51 | 5.699 | <0.001 |
| 1 | C34MLMIN | 3.7 | 0.64 (33) | 0.66 | 4.568 | <0.001 |
| 1 | C34MLMAX | 0.8 | 1.73 (33) | 1.04 | 0.881 | >0.2 |
| 2 | C56ZMAX | 0.6 | 0.69 (32) | 0.36 | 0.246 | >0.5 |

vertebrae; and a unit that contained a head (Head 2) and five cervical units. A second head (Head 1) with four cervical vertebrae and fragments of a fifth had also been discovered; however, the fifth cervical unit was sufficiently fragmented to render measurement imprecise. The authors report several observations taken upon the cervical vertebrae of the trunk and the head/neck units, including vertical diameter of the bodies, maximum distance between transverse processes, and maximum distances between articular processes. It is assumed here that the last-mentioned measure is comparable to ZMAX, although the textual definition of the measurement is not explicit. Glaister and Brash also report data for a single control set of vertebrae with age, sex, and population unspecified.

As is evident in Table 7, the value for ZMAX in the Ruxton example is compatible with the Terry Collection statistics. In addition, the $t$ test probability estimate of $P > 0.50$ strongly prevents rejection of the null hypothesis that the Ruxton C56ZMAX value is not significantly different from the Terry Collection mean. Although the Ruxton remains are reported to differ from the study sample in both age and racial group, our data clearly do support Glaister and Brash's carefully drawn conclusions of congruence between the cervical vertebrae of the trunk and those associated with Head 2.

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