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**TECHNICAL NOTE**

**ANTHROPOLOGY**

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# The Configuration of Cervical Spinous Processes in Black and White South African Skeletal Samples

**ABSTRACT:** The present study investigates the frequency of bifidity/nonbifidity in the black and white South African populations. Four-hundred skeletons of known race, sex, and tribal group were examined. Spinous processes were classified as bifid (bifurcate and cleft subtypes) and nonbifid (obtuse, pediculate, acinate, and clavate subtypes). Statistical analysis using the chi-squared probability test ($p < 0.05$) was carried out. Bifid spinous processes were present significantly more frequently in the white sample (58.9%) than in the black (31.6%). A bifid spinous process occurred most commonly in C2 (89%) followed by C5 (83%), C4 (79%), C3 (59.4%), and C6 (41.7%) in the white sample. A similar order of decrease in bifidity occurred in the black sample. C2 most commonly displayed the bifurcate subtype of spinous process, while the clavate subtype of nonbifid spinous process was the most common in both populations. The significantly higher frequency of bifidity in the white South African sample when compared to the black sample may suggest a population difference.

**KEYWORDS:** forensic science, forensic anthropology, cervical vertebrae, spinous processes, bifidity, human variation, nonmetric traits, population difference

The observation of morphological variability on the human skeleton is as old as the study of human anatomy itself. Nonmetrical traits were of occasional interest to early physical anthropologists who treated them in a purely descriptive manner. Skeletal studies based upon the analysis of nonmetrical traits of the human skeleton have since been used extensively in studies of archaeological populations as markers of population differences (1,2). These differences play a very important role in the determination of race, especially in forensic identification.

In humans, there are seven cervical vertebrae. They are characterized by a foramen in each transverse process. Cervical vertebrae three, four, five, and six (C3, C4, C5, and C6) are typical, having a small but relatively broad body, a large and roughly triangular vertebral foramen, and a short and possibly bifid spinous process. The atlas (C1) has no true spine and consists of two lateral masses connected by a short anterior and longer curved, posterior arch. The axis (C2) is characterized by the vertically projecting dens. The seventh cervical vertebra is characterized by a long club-shaped spinous process and is called the vertebra prominens. To the cervical spinous processes are attached the ligamentum nuchae and the numerous deep extensor muscles of the neck, including the semispinalis cervicis and thoracis, multifidus, and the interspinales.

*Cunningham's Textbook of Anatomy* (3) describes the spinous processes of the third to the fifth cervical vertebrae as "short and bifid at the free end." Most standard anatomical texts give condensed and simplified descriptions of this feature. More detail, however, is given by Morris (4) who wrote "as a rule among Europeans, the second, third, fourth and fifth vertebrae possess bifid spines… Sometimes the sixth has a bifid spine, and, more rarely, the seventh presents the same condition." He goes on to say that "the cervical spinous processes are relatively shorter and more stunted in Negroes (black) than in Europeans (white), and, as a rule, are simple (that is non-bifid)." He notes further that the only cervical vertebra that presents a bifid spine in all races is the axis and that even this may be nonbifid in the Negro (black), and occasionally in the European. Shore (5) carried out studies on the vertebral column and on the shape of the cervical spinous processes in black and white South African population groups. He found a significantly higher incidence of nonbifidity in the black South African sample than in the white sample. The present study used the same criteria in assessing bifidity/nonbifidity as Shore (5); however, the number of skeletons assessed in the present study (300 black and 100 white) were much larger than Shore's study (71 black and 11 white). Lanier (6), studying vertebral variations in skeletons from American museum collections, also found a much higher frequency of bifid spinous processes in European (white) populations than those of African (black) descent.

The present study investigates the following:

- The incidence of bifidity/nonbifidity in the black and white South African populations.
- Whether differences between the black and white South African population groups exist.
- Whether any intertribal differences within the black South African population exist.
- Whether any sex differences within the black and white population groups exist.

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## Materials and Methods

A total of 400 skeletons (300 South African blacks and 100 South African whites) were examined for the configuration of the cervical spinous processes. South African blacks are grouped into six major tribes: Natal Nguni, Cape Nguni, Sotho, Tsonga, Venda, and Swazi. The Natal and Cape Nguni constitute *c.* 66% of the entire black population, the Sotho 28.1%, and the remainder only 5.9% (7). In this study, the skeletal material was drawn from the Natal Nguni, Cape Nguni, and Sotho tribal groups, the three most numerous of the six tribal groups.

The white population of South Africa is not indigenous to the country. The first white people to settle in South Africa were the Dutch. They were followed by the French, English, and other European immigrants. The white sample in this study was not divided into the different nationalities, because such records were not available. The skeletons were thus grouped together as a sample representative of South African whites (http://www.southafrica.info/about/people/population.html [accessed July 21, 2010]).

The Raymond A. Dart collection of human skeletons housed in the School of Anatomical Sciences at the University of the Witwatersrand was used as the source of the sample. The collection was started in 1924, and the bulk of the skeletons were collected by the 1970's. Most of the skeletons in this collection have been derived from hospital sources, and hence, they are of known ethnic group, tribal subgroup, sex, and stated age.

The black South African sample was equally divided into three major tribal groups (100 Natal Nguni, 100 Cape Nguni, and 100 Sotho) to examine if any intertribal differences existed. The three tribal groups as well as the white South African sample were further subdivided into 50 male and 50 female skeletons to test for any sex differences.

The age range for the South African black sample was between 12 and 86 years. The majority of individuals (males and females), which comprise 79% of the total, fell into the third ($n$ = 48), fourth ($n$ = 62), fifth ($n$ = 66), and sixth ($n$ = 61) decades. The remaining 21% fell outside these limits. The age range for the white South African sample fell between 15 and 95 years. The majority of the white individuals (males and females), which comprised 73% of the total, fell into the sixth decade ($n$ = 25), seventh decade ($n$ = 17), and the eighth decade ($n$ = 21). The effect of age on bifidity/nonbifidity was not assessed, as the accuracy of age of the older skeletons in the collection was deemed to be in doubt.

The configuration of the spinous processes of C2–C7 was examined. They were classified according to the scheme suggested by Shore (5). The processes were first grouped according to whether a bifid process was present or absent. Shore's criterion that any spinous process having a dorsal groove deeper than 1 mm is "bifid" was adopted. The two main groups were further subdivided as follows:

- Bifid
  - o Bifurcate—with divergent alae (Fig. 1).
  - o Cleft—with nondivergent or parallel alae (Fig. 2).
- Nonbifid
  - o Acinate—pointed and tapering (Fig. 3).
  - o Obtuse—blunt ended and irregular (specimens may be pyramidal or conical in shape) (Fig. 4).
  - o Pediculate—stud-like with a blunt expanded end attached by a short pedicle to the vertebral arch (Fig. 5).
  - o Clavate—long and club-like (Fig. 6).

Statistical analysis using the chi-squared probability test was carried out to test the variation in frequency of bifid/nonbifid

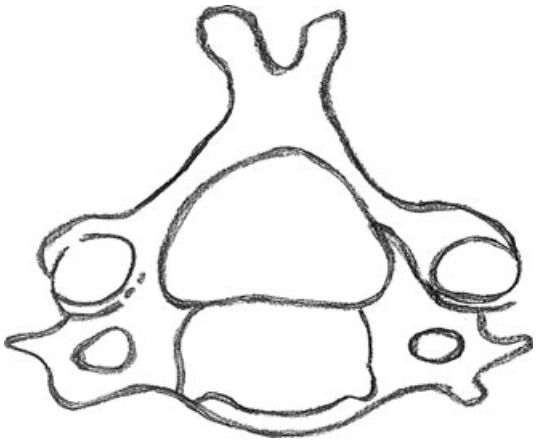

FIG. 1—*Bifid spinous process of the cleft subtype (fourth cervical vertebra).*

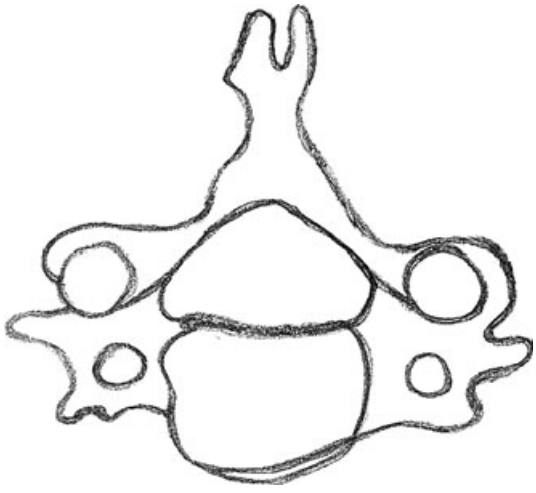

FIG. 2—*Bifid spinous process of the bifurcate subtype (fifth cervical vertebra).*

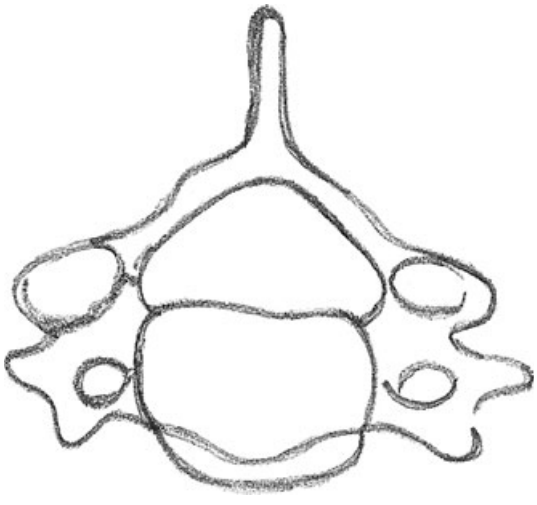

FIG. 3—*Nonbifid spinous process of the acinate subtype (fifth cervical vertebra).*

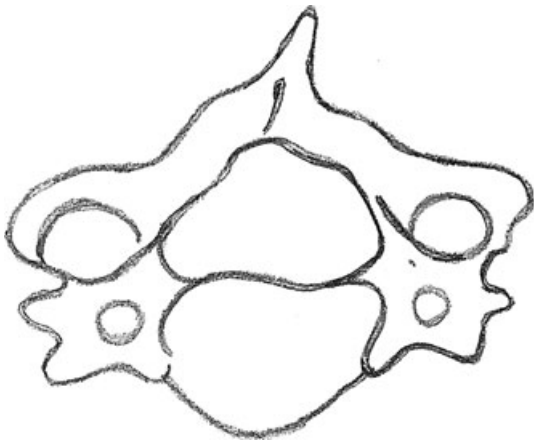

FIG. 4—*Nonbifid spinous process of the obtuse subtype (fourth cervical vertebra).*

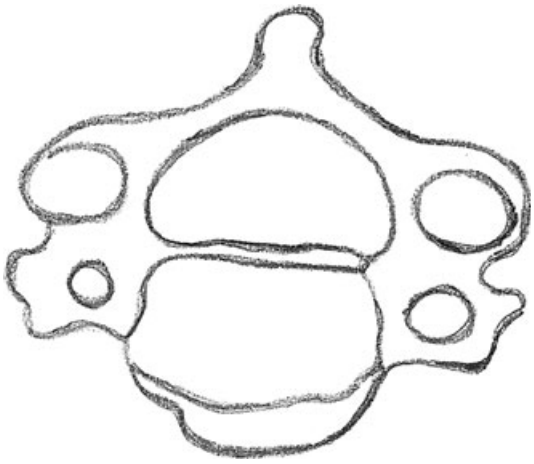

FIG. 5—*Nonbifid spinous process of the pediculate subtype (third cervical vertebra).*

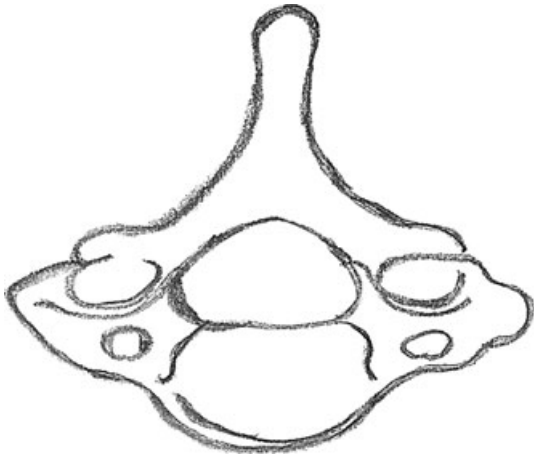

FIG. 6—*Nonbifid spinous process of the clavate subtype (seventh cervical vertebra).*

cervical spinous processes between the tribes, sexes, and races. The 5% level of significance ($p < 0.05$) was accepted as the level of statistical significance in this study. Because of some of the cervical spinous processes being broken, the total number of processes examined did not always correlate with the total number of skeletons examined.

## Results

A preliminary analyses of the bifidity of spinous processes in the men and women and the three tribal groups (Cape Nguni, Natal Nguni, and Sotho) showed no statistical differences ($p < 0.05$). Thus, data for the sexes and intertribal groups are not separated, but combined.

### *Bifid Cervical Spinous Processes*

In the black South African sample, bifid cervical spinous processes were present in 546 cervical vertebrae. This gives a frequency of 31.6% of a total of 1729 spinous processes (Table 1). The second cervical vertebra presented with a significantly ($p < 0.05$) higher frequency of the bifid spinous process and was present in 251 of 300 spinous processes (83.7%). The fifth cervical vertebra (C5) showed the second highest incidence of bifidity (36.0%), followed by C4 (27.6%), C3 (21.5%), and C6 (17.5%). The seventh cervical vertebra showed bifidity in only one vertebra (0.4%).

In the white sample of 586 vertebrae, 345 (58.9%) had bifid spinous processes (Table 1), and this frequency was significantly higher ($p < 0.05$) than that in South African blacks. The axis vertebra again had the highest incidence of bifidity (89.0%). This was followed by C5 (83.0%), C4 (79.0%), C3 (59.4%), C6 (41.7%), and C7 (2.0%), and this order of decreasing bifidity was similar to that for the black sample. The higher frequency in the white South African sample was a result of the significantly higher frequencies of bifidity ($p < 0.05$) in C3, C4, and C5 when compared with the corresponding vertebrae in the South African black sample.

The bifid spinous processes were subdivided into bifurcate (divergent alae) and cleft (parallel alae). In the South African black sample, the bifurcate type of spinous process was present significantly ($p < 0.05$) more often (60.8%) than the cleft type (39.2%) (Table 2). In the white sample, the bifurcate type was present more often (79.4%) than the cleft type, and this too was significant ($p < 0.05$).When the individual vertebrae were analyzed in the black sample, the axis presented with a significantly ($p < 0.05$) higher frequency of the bifurcate type (86.5%) as opposed to the cleft type (Table 2). Cervical vertebrae 3 through 6, however, showed a higher incidence of the cleft type, although this difference was not statistically significant. In the white South African sample, the bifurcate type of spinous process occurred significantly ($p < 0.05$) more frequently in all cervical vertebrae, C2–C7 inclusive (Table 2). Although the preponderance of cleft spinous processes in C3–C6 in the black South African sample was not significant, the finding may be a characteristic of black cervical vertebrae.

### *NonBifid Cervical Spinous Processes*

The frequency of the various subtypes of nonbifid cervical spinous processes in the three tribal groups and the combined black and white South African samples is illustrated graphically in Figs. 7 through 14. The nonbifid spinous processes were considered in four subclasses—acinate, obtuse, pediculate, and clavate. In all three tribal subgroups, the clavate type of spinous process was the most common. It was 42.6% in the Natal Nguni, 41.1% in the Sotho, and 39.0% in the Cape Nguni. This was followed by the pediculate type, with the Natal Nguni again showing the highest frequency (40.8%), followed by the Cape Nguni (34.6%), and the Sotho (29.7%). The obtuse type was present less frequently in both the Cape Nguni (13.6%) and Natal Nguni (13.2%) subgroups. The lowest frequencies were for the acinate type in the Cape Nguni (12.8%) and Natal Nguni (3.4%) and for the obtuse type (10.3%)

TABLE 1—*The frequencies of bifid and nonbifid cervical spinous processes in the black and white South African samples.*

| | Vertebrae | | | | | | |
|---|---|---|---|---|---|---|---|
| | C2(*n*) | C3(*n*) | C4(*n*) | C5(*n*) | C6(*n*) | C7(*n*) | Total *n* (%) |
| South African White | | | | | | | |
| Bifid | 89 (89.0%)* | 57 (59.4%)† | 79 (79.0%)*† | 78 (83.0%)*† | 40 (41.7%) | 2 (2.0%) | 345 (58.9%)† |
| Nonbifid | 11 (11.0%) | 39 (40.6%) | 21 (21.0%) | 16 (17.0%) | 56 (58.3%) | 98 (98.0%)* | 241 (41.1%) |
| Total | 100 | 96 | 100 | 94 | 96 | 100 | 586 |
| South African Black | | | | | | | |
| Bifid | 251 (83.7%)* | 60 (21.5%) | 79 (27.6%) | 104 (36%) | 51 (17.5%) | 1 (0.4%) | 546 (31.6%) |
| Nonbifid | 49 (16.3%) | 219 (78.5%)* | 207 (72.4%)* | 185 (64%) | 240 (82.5%)* | 283 (99.6%) | 1 183 (68.4%)* |
| Total | 300 | 279 | 286 | 289 | 291 | 284 | 1 729 |

*Statistically significant difference ($p < 0.05$) within either the black or white population sample for each individual vertebra and the combined frequency.
†Statistically significant difference ($p < 0.05$) between black and white population samples for each individual vertebra and the combined frequency.

TABLE 2—*The frequencies of bifurcate and cleft subtypes of bifid cervical spinous processes in the black and white South African samples.*

| | Vertebrae | | | | | | |
|---|---|---|---|---|---|---|---|
| | C2(*n*) | C3(*n*) | C4(*n*) | C5(*n*) | C6(*n*) | C7(*n*) | Total *n* (%) |
| White South African | | | | | | | |
| Bifurcate | 70 (78.7%)* | 51 (89.5%)* | 66 (83.5%)* | 58 (74.4%)* | 27 (67.5%)* | 2 (100%) | 274 (79.4%)* |
| Cleft | 19 (21.3%) | 6 (10.5%) | 13 (16.5%) | 20 (25.6%) | 13 (32.5%) | 0 | 71 (20.6%) |
| Total Bifid (*n*) | 89 | 57 | 79 | 78 | 40 | 2 | 345 |
| Black South African | | | | | | | |
| Bifurcate | 217 (86.5%)* | 25 (41.7%) | 31 (39.2%) | 39 (37.5%) | 19 (37.3%) | 1 (100%) | 332 (60.8%)* |
| Cleft | 34 (13.5%) | 35 (58.3%) | 48 (60.8%) | 65 (62.5%) | 32 (62.7%) | 0 | 214 (39.2%) |
| Total Bifid (*n*) | 251 | 60 | 79 | 104 | 51 | 1 | 546 |

*Statistically significant difference ($p < 0.05$) within either the black or white population sample for each individual vertebra and the combined frequency.

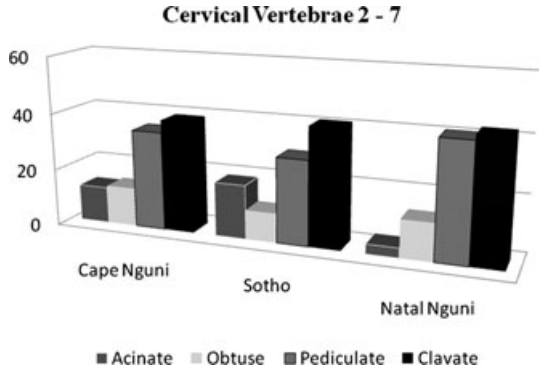


FIG. 7—*Frequency of nonbifid cervical spinous processes in the three tribal samples: cervical vertebrae 2–7.*

in the Sotho. The acinate type was, however, the third highest in the Sotho subgroup (18.9%) (Fig. 7).

In the combined South African black sample, the predominant type of nonbifid cervical spinous process was the clavate (40.8%), followed by the pediculate (34.7%), the obtuse type (13.3%), and lastly the acinate type (12.1%) (Fig. 8). In the South African white sample, the clavate type presented the highest frequency (62.5%). In contrast to the black sample, however, this was followed by the obtuse type (16.5%), the pediculate type (14.8%), and lastly, as with the black sample, the acinate type (6.2%) (Fig. 8). There were, however, no significant differences between black and white samples, and it is noteworthy that the clavate subtype was the most common in both groups and the acinate the least frequent. The predominance of the clavate subtype owed in part to the finding that all seventh cervical vertebrae (in both black and white samples) were of the clavate type.

For C2, the obtuse form overwhelmingly is the more frequent subtype in all samples (Fig. 9). For C3 and C4, the pediculate form is the more frequent subtype for all South African blacks, while the South African whites are more evenly divided between pediculate and obtuse (Figs. 10 and 11). With regard to C5, the Cape Nguni group and the white South African sample mirror each other with the distribution of pediculate/obtuse forms, while all the other South African blacks are pediculate (Fig. 12). Lastly, for C6 and C7, all the groups are overwhelmingly clavate in form (Figs. 13 and 14).

## Discussion

The present study has found consistent differences in the frequency of bifidity versus nonbifidity in a large sample of South

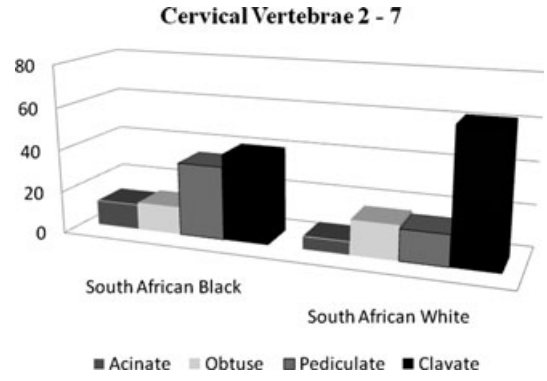


FIG. 8—*Frequency of nonbifid cervical spinous processes in the combined black and white South African samples: cervical vertebrae 2–7.*

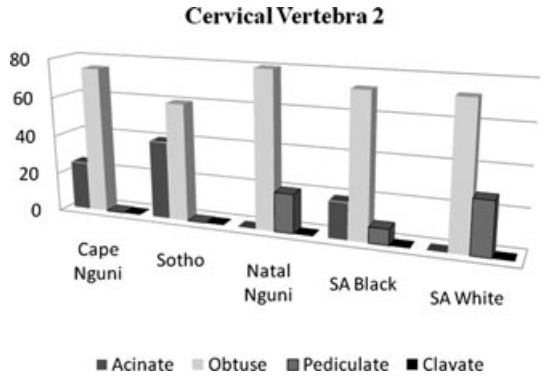


FIG. 9—*Frequency of nonbifid cervical spinous processes in the three tribal groups and the combined black and white South African samples: cervical vertebra 2.*

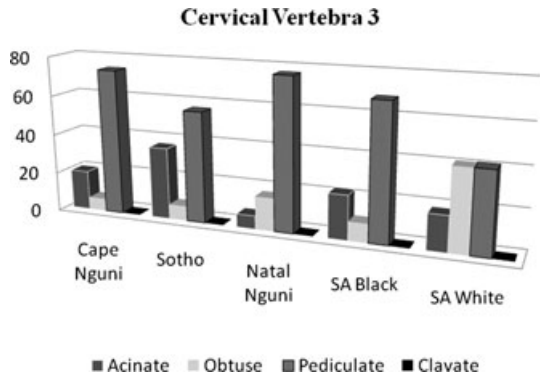


FIG. 10—*Frequency of nonbifid cervical spinous processes in the three tribal groups and the combined black and white South African samples: cervical vertebra 3.*

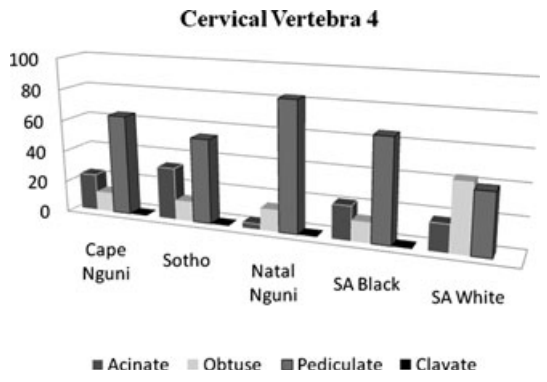


FIG. 11—*Frequency of nonbifid cervical spinous processes in the three tribal groups and the combined black and white South African samples: cervical vertebra 4.*

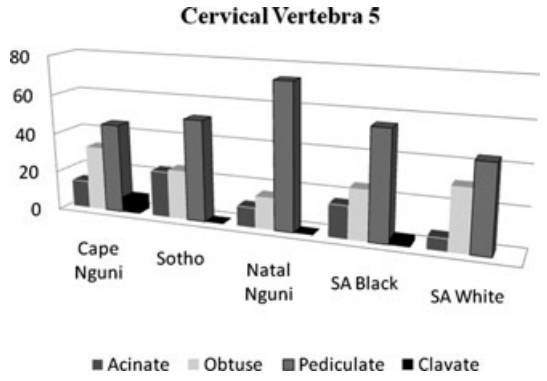


FIG. 12—*Frequency of nonbifid cervical spinous processes in the three tribal groups and the combined black and white South African samples: cervical vertebra 5.*

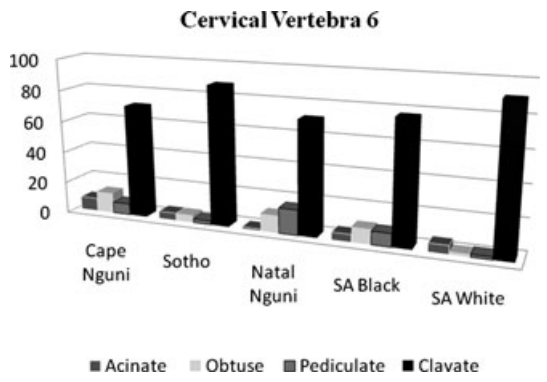


FIG. 13—*Frequency of nonbifid cervical spinous processes in the three tribal groups and the combined black and white South African samples: cervical vertebra 6.*

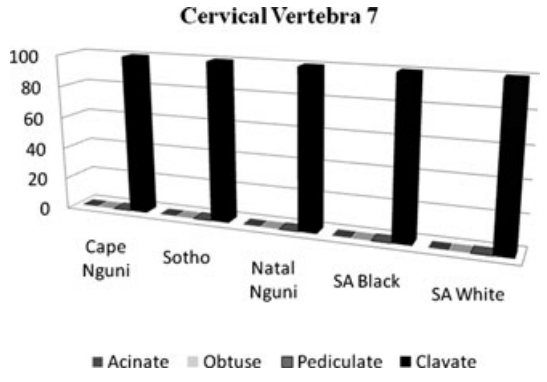


FIG. 14—*Frequency of nonbifid cervical spinous processes in the three tribal groups and the combined black and white South African samples: cervical vertebra 7.*

African blacks and whites. South African white cervical spinous processes are significantly more bifid (58.9%) than nonbifid (41.1%), whereas nonbifidity is significantly more frequent in South African blacks (68.4%). Furthermore, the present study also confirmed that the axis consistently displayed the bifid character in most individuals in both South African black (83.7%) and white samples (89.0%). At each of the levels from C3 through to C6, South African whites showed a higher frequency of bifidity than South African blacks. Duray et al. (8) found that the frequency of bifidity for American whites at levels C3 to C6 was significantly higher when compared to American blacks. Logistic regression analysis tests performed by Duray et al. (8) demonstrated that C3 and C4 were the most useful variables to suggest that an individual with a bifid spinous process at these levels would have a high probability of being white rather than black.

The incidence of bifidity and nonbifidity in Shore's (5) study of white South African skeletons showed a frequency of 71.6% and 28.3%, respectively. In the present study, the white South African

sample too showed a higher frequency of bifid spinous processes (58.9%) as compared with nonbifid (41.1%). Shore's (5) black sample, however, had a high frequency for nonbifid spinous processes (78.8%). This was even higher than that of the present study (68.4%). A trend is thus shown toward nonbifidity in both Shore's (5) black sample and that of the present study. The difference in results between the present study and that of Shore's (5) could possibly be because of inter-observer differences in the scoring of nondiscrete traits and also because of the present study assessing 400 skeletons as opposed to only 82 (11 white and 71 black) studied by Shore (5).

The finding that bifid cervical spinous processes occur almost two times more frequently in the white South African sample (58.9%) than in the black sample (31.6%) of the present study as well as in Shore's (5) study (71.6% as compared with 28.3%) may suggest a population difference with regard to this trait.

The findings in the present South African sample of predominantly clavate spinous processes differs from Shore's (5) finding that the pediculate type was predominant in his study, followed by the clavate. In the San sample studied by Shore (5), the clavate type was found to be the predominant type followed by the pediculate type. This corresponds with the results of the black sample in the present study.

The results of the present study show no significant differences among the four subtypes of nonbifid cervical spinous processes between black and white samples. There is thus no indication of a population difference between the black and white samples in this regard.

Von Eggeling's (9) extensive comparative studies of the skeletal and muscular systems of man, anthropoids, and monkeys suggested that variations in the bifidity of the cervical spinous processes depend on posture and mobility of the cervical spine. The nonbifid character of the cervical spinous processes that he found in the apes and monkeys was, in his opinion, associated with the incomplete attainment of the movement and erection of the cervical spine and thus, lesser mobility. He attributed the occurrence of nonbifid cervical spinous processes to the lesser degree of development of the semispinalis cervicis in spines of lesser mobility.

Von Eggeling's (9) study in the ontogeny of bifidity observed that the "bifid" condition of the cervical spinous processes could be recognized in the cartilaginous stage of development. He further observed that some of the commonly nonbifid sixth and seventh spinous processes exhibit a bifid condition in the cartilaginous stage. Furthermore, he observed that in the second half of the first year, bifidity of the cervical spinous processes begins to disappear, first in the seventh and then in a cranial direction. He suggested that the bifid quality of the cervical spinous processes in white skeletons had entered a phase of regression and that the increased bifidity of these processes was a transient product of evolution, which started in a post-Neanderthal period and would eventually disappear. Thus, according to Von Eggeling, the results for the white sample in the present study would seem to indicate that the change of type of cervical spinous processes indicated during development that is bifid to nonbifid, has now attained virtual completion in the seventh cervical vertebra, but has not attained an appreciable frequency in the middle members of the cervical column. The results for the black sample in the present study, however, would seem to be more stable in terms of Von Eggeling's (9) findings, as the cervical spinous processes have tended to retain their nonbifid character acquired during development. It is possible that there is a developmental explanation for the preponderance of nonbifid spines in cervical vertebrae 3 through to 7 of the South African black sample. This is supported by the finding of a preponderance of nonbifidity in Shore's (5) South African black sample.

The data of the present study clearly show that there is difference in bifidity/nonbifidity in the cervical spinous processes between the black and white South African populations. Further studies using logistic regression analysis would provide further evidence for using bifidity of cervical spinous processes in addition to other traits in the determination of race from the skeleton.

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