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MORPHOLOGICAL VARIATIONS OF THE CERVICAL VERTEBRAE IN SAMPLES OF SOUTH AFRICAN BLACK AND WHITE POPULATION GROUPS

by

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A dissertation submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Master of Science.

Johannesburg 1996

ABSTRACT

The frequency of variations in nine morphological features of the cervical column in a South African (S.A.) black and white sample of human skeletons was investigated to determine whether there was a greater degree of morphological variability in the black as compared with the white sample. These findings were compared with other population groups. Intertribal, sex and side differences were examined. The possible aetiology of these variations was explored.

The seven cervical and the first three thoracic vertebrae of 300 S.A. black (100 Sotho, 100 Cape Nguni and 100 Natal Nguni) and 100 white skeletons from the Raymond A. Dart Collection were examined. The following non-metrical variations were recorded: numerical variation, occipitalization of the atlas, cervical rib, spina bifida occulta, configuration of the cervical spinous processes, bipartite foramen transversarium, bipartite superior articular facets of the atlas, posterior bridge of the atlas and ossification of the apical ligament of the dens of the axis. The Chi-square and Fischer's exact probability statistical tests were used to analyse tribal, population and sex differences.

No major intertribal differences were found among the N.Nguni, Sotho or C.Nguni tribal subgroups which were then pooled to provide a sample representative of S.A. blacks.

A reduction to six cervical vertebrae was present in only one column, a S.A. black male. Occipitalization of the atlas was not present in either the black or white group. A cervical rib was present more often in blacks than in whites. Spina bifida occulta was present in higher frequencies in the atlas than in vertebrae of the cervico-thoracic region in both black and white samples. Non-bifid cervical spinous processes were characteristic of black spines. Bipartite foramina transversaria occurred significantly more frequently in S.A. whites than in blacks; the sixth cervical vertebra had the highest frequency of this feature. In the white sample there was a somewhat higher frequency of bipartite superior articular facets of the atlas and ossification of the apical ligament when compared with the black sample. A

complete posterior bridge of the atlas was present more frequently in S.A. blacks than whites.

A low degree of sexual dimorphism for all the variations in the cervical spine was found save for that of cervical rib where the frequency for black males was significantly higher than that for females. It was noteworthy that there was a female preponderance for spina bifida occulta in both black and white groups.

DECLARATION

I declare that this dissertation is my own, unaided work. It is being submitted for the degree of Master of Science in the University of the Witwatersrand, Johannesburg. It h~ ~ not been submitted before for any degree or examination in any other university.

_____

Riaze Asvat

_____ day of _____, 1996

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I am grateful to the Biostatistics Department of the Medical Research Council for assisting me with the statistical analyses carried out in this study.

I am grateful to the Department of Anatomical Sciences for allowing me to use the Raymond A. Dart Collection of skeletons.

LIST OF ABBREVIATIONS

S.A.	-	South African
N.Nguni	-	Natal Nguni
C.Nguni	-	Cape Nguni
M	-	Male
F	-	Female

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CHAPTER 1

INTRODUCTION

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. Important early studies employing variations to describe populations include Le Double's "Traites de Variation de la Colonne Vertebrale" (1912). This study examined almost every possible variation of the vertebral column. Skeletal studies based upon the analysis of non-metrical traits of the human skeleton have since been used extensively in studies of archaeological populations as markers of population differences (Berry 1974, Finnegan 1978). All series of skeletons display some variability irrespective of the homogeneity of the populations which they represent. Variability is characteristic of all forms of life and thus the study of the variability of man is the study of human races.

In the human there are seven cervical vertebrae out of a total of twenty four presacral vertebrae. The cervical vertebrae are characterised by a foramen in each transverse process. Cervical vertebrae three, four, five and six are typical, having a small but relatively broad body, a large and roughly triangular vertebral foramen and a short and usually bifid spinous process. The atlas is unique in lacking a body; its centrum is fused with that of the axis to form the dens. Moreover, it has no true spine and consists of two lateral masses connected by a short anterior and a longer curved posterior arch. The superior surface of the posterior arch of the atlas is characterised by a groove for the vertebral artery and first cervical spinal nerve. The axis is characterised by the vertically projecting dens, which articulates with the back of the anterior arch of the atlas. The dens is considered developmentally to have been the centrum of the atlas. 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 numerous deep extensors of the neck, including semispinalis cervicis and thoracis, multifidus and the interspinales.

Reduction in the number of the cervical vertebrae to six is a rare occurrence in mammals and this region is numerically one of the most constant in the vertebral column (Allbrook, 1955). Comparative studies of the vertebral column on different population groups have suggested that African material yielded more morphologic variability in this regard than in other race groups (Allbrook, 1955). Shore (1930) carried out studies on the vertebral column and on the shape of the cervical spinous processes in black and white S.A. population groups (Shore, 1931). He found a significantly higher incidence of variations in the vertebral column as well as of non-bifidity in the black S.A. sample, than in the white sample. Shore (1930) concluded that the vertebral column of the S.A. Negro is "strikingly unstable with an incidence of each abnormality higher than is recorded in other records." The present study investigates Shore's results in larger samples of S.A. blacks and whites.

Another variation sought for in the present study was the frequency of spina bifida occulta. Great interest has been shown in the geographical distribution and racial incidence of spina bifida. A report by the World Health Organisation Scientific Group (1970), summarising the evidence regarding the frequency of spina bifida, concludes that "there is little doubt that there are real variations in the frequencies of spina bifida in different communities". Most of the published material dealing with the incidence of spina bifida is almost exclusively concerned with the clinical condition of spina bifida aperta in the lumbo-sacral region of the vertebral column. There is little information on the relatively benign condition of spina bifida occulta in the cervical and upper thoracic regions. The present study thus examines the incidence of spina bifida occulta in these two vertebral regions. The occipito-cervical region was additionally examined for the rare condition of occipitalization of the atlas. Variations of the superior articular facets of the atlas were also examined. In the cervico-thoracic region, the incidence of cervical rib was investigated. Its presence may have clinical consequences.

The use of non-metrical traits of the skeleton to distinguish between population groups is employed by many physical anthropologists. Despite many studies, anthropologists still dispute whether metrical or non-metrical

studies are the more useful models for research (Corruccini, 1974). For example, anthropologists disagree over the relative value of metrical versus non-metrical variables for the calculation of biological distance between populations (Gaherty, 1973; Corruccini, 1974). This study uses only non-metrical variables.

Gruneberg (1952), conducted genetic experiments by crossing pure lines of mice in an attempt to determine the mode of inheritance of different skeletal variations. The study found a great deal of skeletal variation in the different mouse stocks which had been inbred for a number of generations. The results showed that no simple genetic interpretation was possible. Subsequent to this, Searle (1954) investigated the non-genetic factors which affect trait appearance. He studied twelve variations in one strain of mice and nine in another and examined the contributions to variation from sex, litter size, parity, maternal age and gestation length. All of these factors were found to have some effect, particularly asymmetry, sex, maternal age and litter size. However, intangible factors accounted for over eighty percent of the total variation in three-quarters of the variants. Berry and Searle (1963) proposed a credible explanation of how genetic and environmental factors interact using the concept of "genetic assimilation". This means that a trait which is at first produced by an environmental stimulus will eventually come under genetic control. Those workers in favour of non-metrical analysis have stressed that non-metrical traits are not influenced by side, sex or age of the individual, and are not correlated with each other. Searle (1954) has shown that for mice, there is a tendency for right side asymmetry of traits. However, Berry and Berry (1967) believe that in most cases the degree of significant differences in side incidence is low and, therefore, the sides could be justifiably pooled. The present study will, however, examine side differences as well as pooled samples.

Different workers have developed various methods for dealing with sex variation in the frequencies of human non-metrical traits. Gaherty (1973) pooled samples where traits showed no sex association. Corruccini (1974) proposed that the only proper way was to keep sexes separate. The present study initially examines males and females separately. Thereafter, if no significant sex differences are present, the results are pooled.

Researchers who have studied the S.A. tribal groups (Shapiro, 1951; de Villiers, 1957; de Beer Kaufman, 1975), found little or no intertribal differences and pooled the results from the various subgroups to form a representative S.A. black sample. This study will initially examine tribal frequencies for each of the non-metrical traits examined. The tribal subgroups will thereafter be pooled to form a sample representative of S.A. blacks.

The objectives of this dissertation, which is a descriptive and statistical study of nine non-metrical traits of the cervical column, is to determine:

1. Whether there is any morphological variability among the different tribal groups of the black S.A. sample, represented by the C.Nguni, N.Nguni and Sotho.
2. Whether there is a greater degree of morphological variability in the S.A. black sample as compared to the S.A. white sample.
3. Whether there are significant sex differences for individual traits.
4. Whether there are any differences between left and right sides for individual traits.
5. The possible aetiology of these variations.

In the layout of this dissertation each trait will be allocated a separate chapter in which the results, discussion and conclusion for that particular trait will be presented.

CHAPTER 2

MATERIAL

The material used in this study will be considered under the following headings:-

A. The Source Populations.

B. The Cervical Column: Ethnic, Sexual and Age Breakdown of the Series.

A. The Source Populations

The material for this study was drawn from two S.A. population groups, namely, S.A. black and S.A. white. Over the years, various terms have been used in scientific literature to refer to these groups. The black group has been designated variously as 'Native', 'Bantu', 'African', 'South African Negroid' and 'South African Negro' and the white group as 'European', 'Caucasian' or 'Caucasoid'. The Council of the Anatomical Society of Southern Africa, in May 1992 suggested that the following terms be accepted: S.A. black and white. In keeping with this decision, the terms S.A. black and white will be used in this study to refer to the two population groups.

A.1 *The South African (S.A.) Black Sample*

S.A. blacks are grouped into six major tribes: Natal Nguni, Cape Nguni, Sotho, Tsonga, Venda and Lemba. According to van Warmelo (1974) the Natal and Cape Nguni constitute approximately 66% of the entire black population, the Sotho 28,1% and the remainder only 5,9%. In this study, the S.A. black material was drawn from the N.Nguni, C.Nguni and Sotho tribal groups, the three most numerous of the six major tribal groups. The N.Nguni are represented by a sample from the Zulu tribe, the C.Nguni by a sample from the Xhosa tribe and the Sotho group has representative samples from South, Western and North Sotho tribal sub-groups.

A.2 *The South African (S.A.) White Sample*

The white population of South Africa are 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 E.ropean immigrants. The white sample in this study was not divided into the different nationalities, because

such records were not available. The individuals were thus grouped together as a sample representative of S.A. whites.

B. The Cervical Column: Ethnic, Sexual and Age Analysis of the Series

B.1 *The South African Black Sample*

The Raymond A. Dart Collection of human skeletons housed in the Department 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 material used in this study consists of 300 cervical columns from the three major tribal divisions of the S.A. black population group.

a. *Chiefdom*: The cervical columns (Table 1) are drawn from i) the Natal Nguni represented by 100 individuals of the Zulu tribe, ii) the Cape Nguni represented by 100 individuals of the Xhosa tribe and iii) the Sotho represented by 100 individuals of the Sotho tribe.

Table 1: The Composition of the South African Black Cervical Columns

GROUP	CHIEFDOM OR TRIBAL DIVISION	TRIBE	MALE	FEMALE	TOTAL
S.A. BLACK	Natal Nguni	Zulu	50	50	100
	Cape Nguni	Xhosa	50	50	100
	Sotho	Sotho	50	50	100
	TOTAL S.A. BLACK SAMPLE		150	150	300

Information on the chiefdom of the subjects represented in the present study is, as stated, obtained from hospital records. The individuals were drawn largely from the local Witwatersrand black population. This population is undergoing detribalisation, but by the 1970's this process had not affected the majority of the adult population to the extent that they themselves were products of intertribal marriages (de Villiers, 1957). For this reason the

information on the chiefdoms of origin of the skeletons in the Raymond A. Dart Collection may be accepted as probably reliable, except perhaps for some of the most recently acquired skeletons. This problem was overcome by using skeletons that were accessioned prior to 1975. Individuals whose chiefdom was not specified were excluded from this study.

b. *Sex:* Precise information as to the sex of the individuals is available from hospital records. Of the 300 cervical columns examined, 150 were male and 150 female.

c. *Age:* The age of the individual stated on the death certificate is not always accurate, since not all S.A. blacks were certain of their date of birth. Further, if the patient was unable to give this information on admission to hospital, age was often estimated by the hospital staff. In this study the range of stated age falls between 12 and 86 years (Table 2). Table 2 shows that the majority of individuals (males and females) which comprise 79% of the total, fall into the third (48), fourth (62), fifth (66) and sixth (61) decades. The remaining 21% of the total fall outside these limits. The majority of the males, however, fall within the fifth decade and the majority of the females within the sixth decade.

B.2 *The South African White Sample*

The sample of S.A. white cervical columns consists of 100 skeletons, 50 male and 50 female, and was drawn from the Raymond A. Dart Collection of human skeletons. The nationalities of the cadavers from which these skeletons were derived were not known: they are listed as S.A. Caucasoid in the record books.

a. *Age:* The age range for the S.A. white sample of cervical columns falls between 15 and 95 years (Table 3). Analysis of the table shows that the majority of the white individuals (males and females), which comprise 73% of the total, fall into the sixth decade (25), seventh decade (17) and the eighth decade (21). This differs from the black sample where the majority of the

Table 2: Distribution of Age and Sex in a Series of 300 Black South African Cervical Columns

AGE IN YEARS	MALES		FEMALES		MALE + FEMALE	
	n	%	n	%	n	%
10 - 19	5	3.3	2	1.3	7	2.3
20 - 29	15	10.0	11	7.3	26	8.7
30 - 39	27	18.0	21	14.0	48	16.0
40 - 49	31	20.7	31	20.7	62	20.7
50 - 59	38	25.4	28	18.7	66	22.0
60 - 69	20	13.3	41	27.4	61	20.3
70 - 79	12	8.0	11	7.3	23	7.7
80 - 89	2	1.3	5	3.3	7	2.3
	150	100	150	100	300	100

n = number of skeletons

Table 3: Distribution of Age and Sex in a Series of 100 White South African Cervical Columns

AGE IN YEARS	MALES		FEMALES		MALE + FEMALE	
	n	%	n	%	n	%
10 - 19	1	2.0	0	0	1	1.0
20 - 29	0	0	2	4.0	2	2.0
30 - 39	1	2.0	0	0	1	1.0
40 - 49	5	10.0	3	6.0	8	8.0
50 - 59	8	16.0	4	8.0	12	12.0
60 - 69	13	26.0	12	24.0	25	25.0
70 - 79	14	28.0	13	26.0	27	27.0
80 - 89	7	14.0	14	28.0	21	21.0
90 - 99	1	2.0	2	4.0	3	3.0
	50	100	50	100	100	100

n = number of skeletons

individuals (male and female) fall between the third and sixth decades. When age distribution is analysed for males and females separately, the majority of the white males fall within the seventh decade an the majority of the white females fall within the eighth decade.

CHAPTER 3

METHODOLOGY AND TECHNIQUES

The methods and techniques used in this study of the cervical column of S.A. black and white groups are considered under the following headings:

A. Non-metrical methods.

B. Statistical methods.

A. Non-Metrical Methods

The cervical vertebrae and the first three thoracic vertebrae were first articulated with one another by moulding plasticine onto the superior and inferior articular facets of each of the vertebrae, and then articulating them in sequence with one another. This was done to exclude from the survey any cervical columns with missing vertebrae. The articulations and general conformation of the vertebrae preceding and succeeding each vertebra examined were strictly scrutinized. The following non-metrical observations were made (Appendix 1):

1. *Numerical Variation*

Addition or reduction to the normal count of seven cervical vertebrae was recorded. Occipitalization of the atlas was not counted as a reduction (see `2' below).

2. *Occipitalization of the Atlas*

This is present when there is fusion of the atlas (C1) with the occiput of the skull. The fusion is between the occipital condyles of the skull and the superior articular facets of the atlas, the transverse processes, anterior arch and/or posterior arch. Assimilation may be unilateral or bilateral. Since the assimilated vertebra has the typical features of a first cervical vertebra in all other respects, it was thus counted as a cervical vertebra.

3. *Cervical Rib*

The transverse processes of the cervical vertebrae (which contain the foramen transversarium) consist of anterior and posterior roots connected by a costotransverse bar. All these parts save for the medial portion of the

posterior root, constitute the homologue of a rib (Williams et al., 1989). Occasionally this costal element may develop into a cervical rib in the seventh cervical vertebra. When present, such a rib may end freely, or it may be bound to the first thoracic rib, or be anchored to the first costal cartilage (by connective tissue, cartilage or bone). Occasionally the cervical rib may possess a costal cartilage that reaches the manubrium. An example of a cervical rib is seen in Figure 1 which shows the seventh cervical vertebra of a black S.A. male with bilateral cervical ribs. In skeletal studies, this rudimentary rib, which is small, may be lost during preparation of the skeleton and its presence may only be detected by the finding of an articular facet on the body of the seventh cervical vertebra. In this study the presence of a cervical rib was recorded on the evidence of such a facet. Its unilateral or bilateral occurrence was noted.

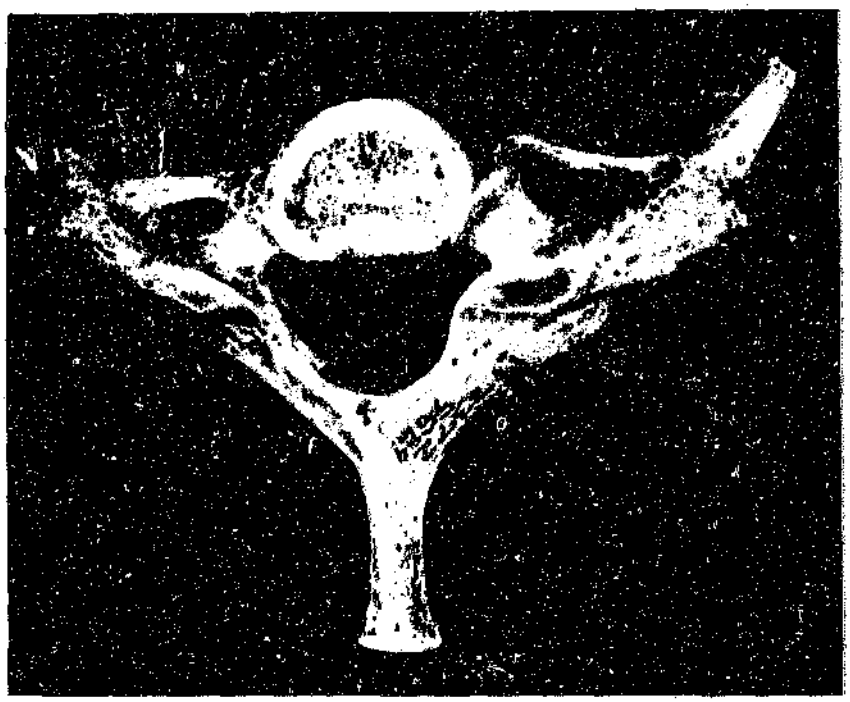

Fig. 1 The seventh cervical vertebra of a black S.A. male presenting with a bilateral cervical rib.

4. *Spina Bifida Occulta of the Cervical and Upper Thoracic Region*

Spina bifida occulta is present when the two halves of the vertebral lamina meet in the midline but fail to fuse. It is thus a midline cleft or defect of the cervical spinous processes (Fig. 3), or in the case of the atlas, in the posterior arch (Fig. 2). It is a benign condition and has no apparent clinical effect on the individual. The presence or absence of spina bifida occulta was recorded in all the cervical and the upper three thoracic vertebrae. Since many workers have reported on the cervico-thoracic junction only, the results for that region will be recorded separately. Initially, the results for all vertebrae examined will be presented.

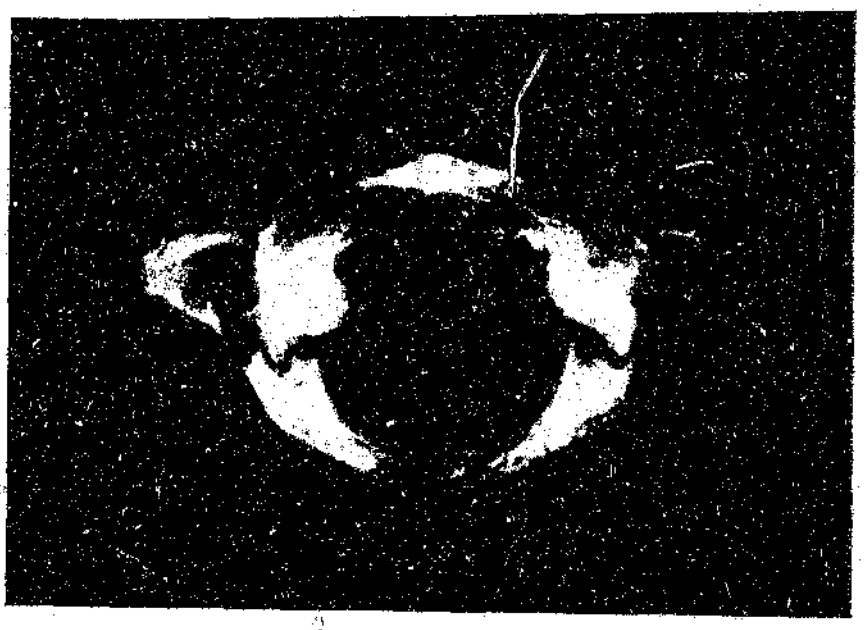

Fig. 2 Spina bifida occulta of the atlas in a white S.A. male.

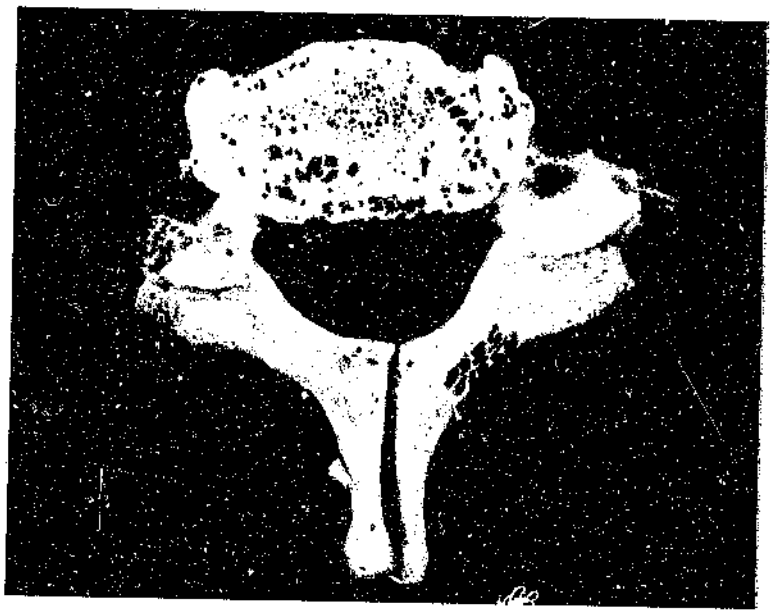

Fig. 3 Spina bifida occulta of the seventh cervical (top) and first thoracic vertebrae (bottom) in a black S.A. male.

5. *Configuration of Cervical Spinous Processes*

The first cervical vertebra has no true spinous process. The posterior tubercle represents a spinous process. The configuration of the spinous processes of C2 to C7 were examined. They were classified according to the scheme suggested by Shore (1931). This classification is illustrated in Figures 4 and 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 1mm is "bifid" was adopted. The two main groups were further subdivided as follows:

a) *Bifid*

   i. Bifurcate - with divergent alae

   ii. Cleft - with non-divergent or parallel alae.

b) *Non-Bifid*

   i. Acinate - pointed and tapering

   ii. Obtuse - blunt ended and squat

   iii. Pediculate - stud-like

   iv. Clavate - long and club-like.

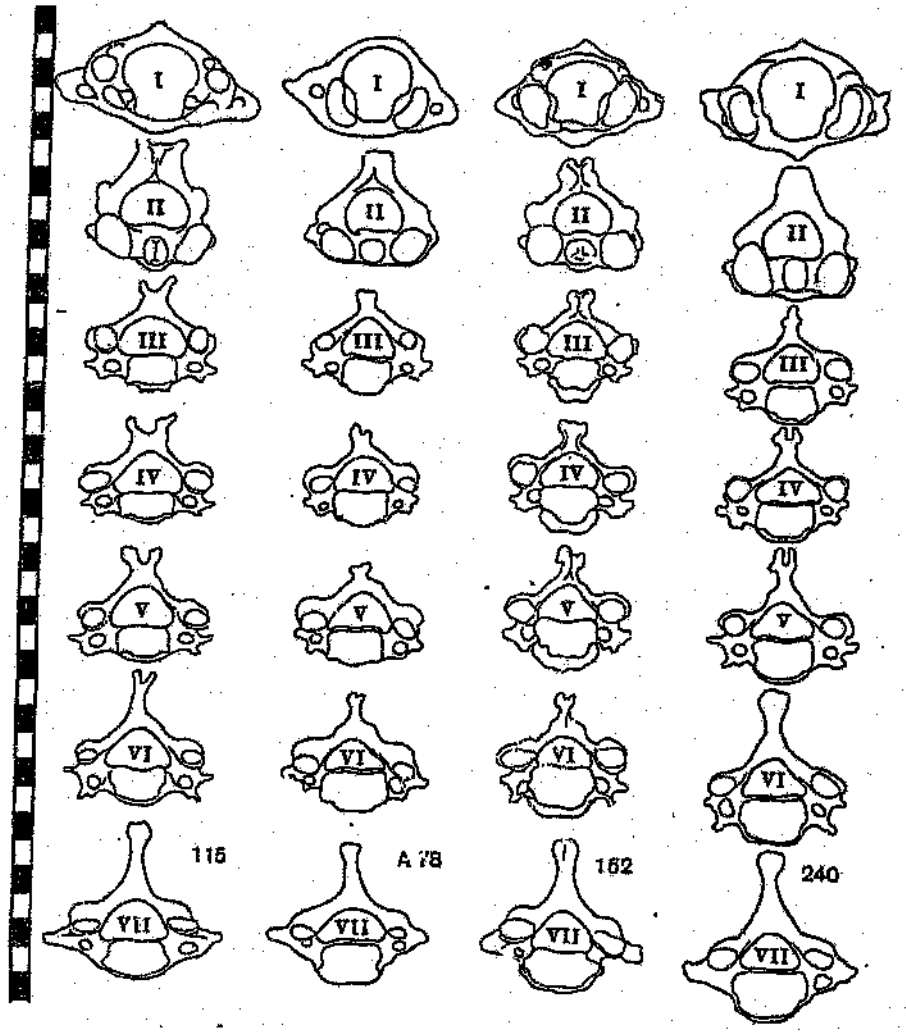

Fig. 4 Bifid Cervical Spinous Processes

Four tracings of cervical columns in norma verticalis are shown. Column No. 115 on the left is European, of Nordic type, No. A 78 is also European, but Mediterranean, while No. 152 represents a S.A. Negro specimen. These three tracings illustrate *bifurcate* spinous processes. The column on the right, No. 240, illustrates the *cleft* type in its fourth and fifth members. A centimetre scale is shown on the left of the tracings (from Shore, 1931).

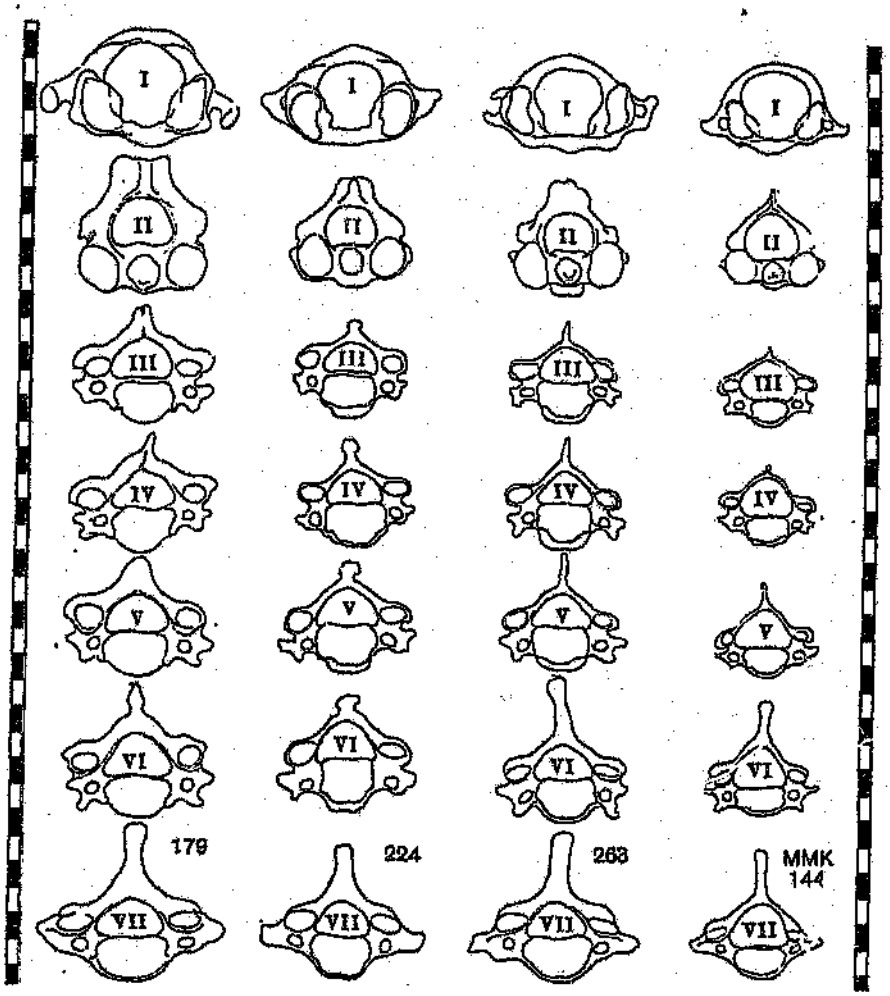

Fig. 5 Non-Bifid Cervical no · Processes

The four types ·i non-bifid cervical spinous processes are illustrated. Vertebrae III, IV and V of vertebral column No. 179 show the *obtuse* type. The *pediculate* type is shown in vertebrae III and VI of specimen No. 224. The columns (Nos. 263 and MMK 144) illustrate the *acinate* type of spinous process. The *clavate* type is shown in each seven·h vertebra of all the columns illustrrted. MMK 144 is a Bushman (San) and the others are S.A. Negroid (from Shore, 1931).

6. Bipartite Foramen Transversarium

The transverse processes of all cervical vertebrae contain the foramen transversarium, which is characteristic of the cervical column. The foramen transmits the vertebral artery (in all but C7), its accompanying venous plexus and a sympathetic plexus. The foramen transversarium is usually single, except for that in the sixth cervical vertebra, where it is commonly bipartite (Williams et al., 1989). The vertebrae in which bipartite foramina transversaria (Fig. 6) occurred were recorded, as well as whether the bipartite foramen was bilateral or unilateral.

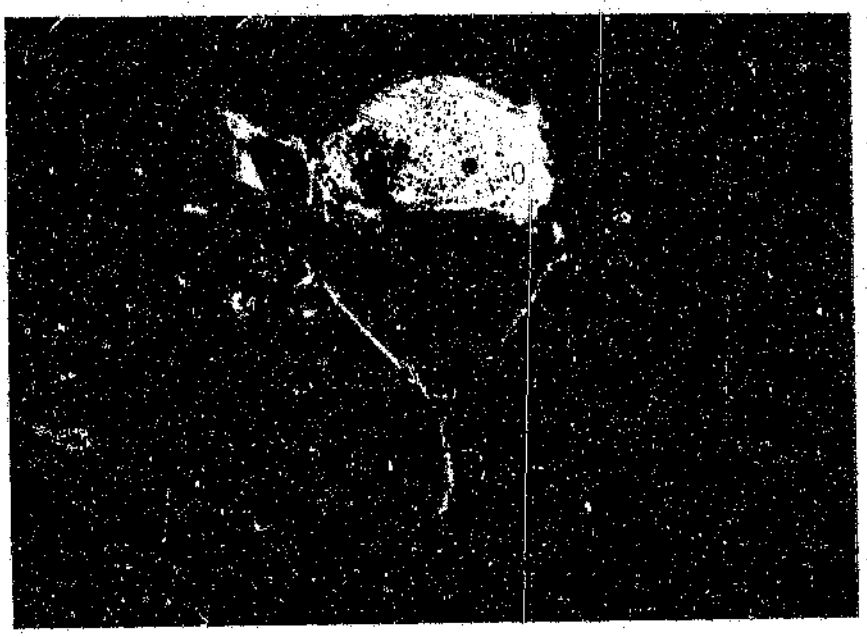

Fig. 6 A bilateral bipartite foramen transversarium present on the sixth cervical vertebra of a S.A. black male.

7. *Bipartite Superior Articular Facet of the Atlas*

This facet is normally long and oval or kidney-shaped. A variation may be present in the form of two distinct facets, separated by a groove or ridge of bone (Fig. 7). The bilateral or unilateral occurrence of this variation was recorded.

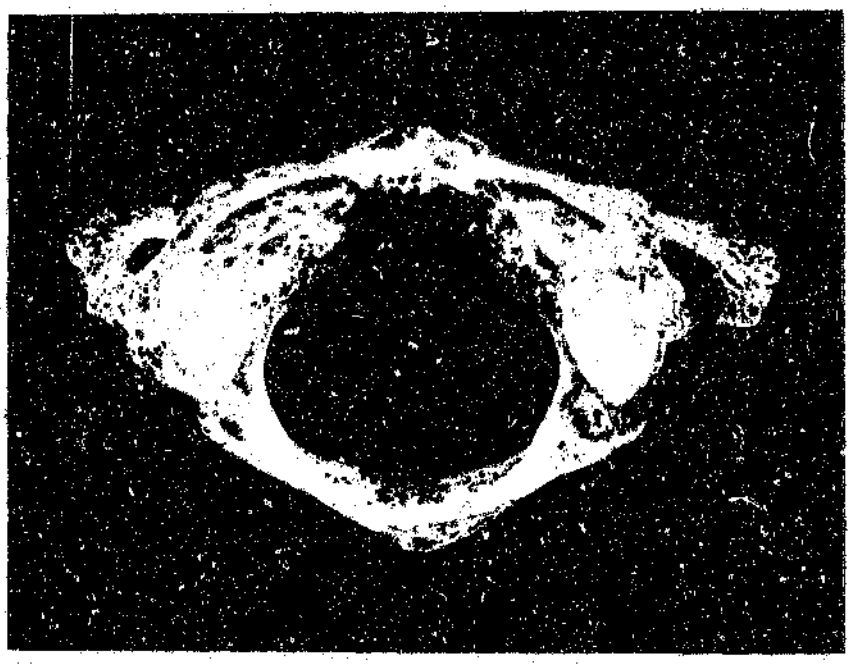

Fig. 7 The presence of a unilateral left bipartite superior articular facet of the atlas in a white S.A. male.

8. *Complete Posterior Bridge of the Atlas*

In this skeletal trait, the groove for the vertebral artery which lies on the upper surface of the posterior arch of the atlas behind the lateral mass, is converted into a foramen by a spicule of bone (Fig. 8). This spicule arches backwards to form a bridge from the upper surface of the lateral mass onto the posterior arch. It was not recorded as present unless a complete bridge was found. The bilateral or unilateral occurrence of this trait was also recorded.

Fig. 8 Complete bilateral posterior bridge of the atlas in a black S.A. male.

9. *Ossification of the Apical Ligament of the Dens of the Axis*

This skeletal trait is an ossification of the apical ligament (Fig. 9) which runs upwards from the tip of the dens of the axis to the clivus of the occipital bone (Anderson, 1968). The presence or absence of this variation was recorded.

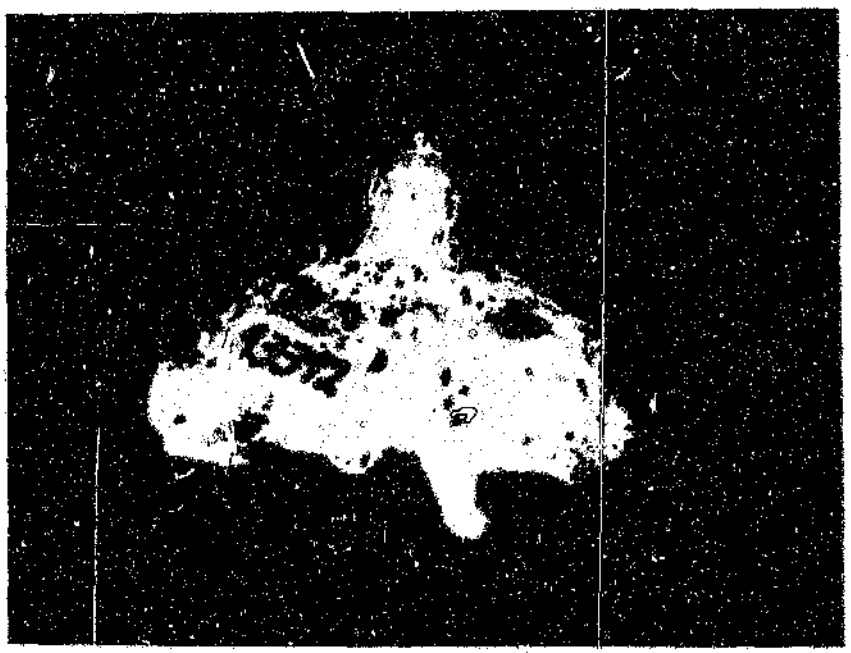

Fig. 9 Ossification of the apical ligament of the dens of the axis in a black S.A. male.

B. Statistical Methods

Two statistical tests were used to test the significance of intergroup and sex differences of the non-metrical features studied. These tests were recommended by the Biostatistics unit of the South African Medical Research Council of the University of the Witwatersrand.

i) *Chi-Square Test*

The value of chi-square was calculated according to the formula:

$$X^2 = \frac{\sum (O-E)^2}{E}$$

The chi-square test was only used when $20>N\leq40$ and the expected value for all cells was greater than or equal to 5.

When $N>40$ and the expected value greater than or equal to 5 for all the cells, then the continuity adjusted chi-square test was used.

ii) *Fisher's Exact Probability Test*

The Fisher's exact probability test was calculated using contingency tables.

The Fisher's exact probability test was only used when,

a) $N\leq20$

b) $N>20$ and the expected value was less than 5 for one or more cell.

The 5% level of significance ($P<0.05$) was accepted as the level of statistical significance of a trait in this study.

The following statistical comparisons were carried out:

A. *Tribal comparisons*

1. Sotho versus C.Nguni versus N.Nguni (males and females combined).
2. Sotho males versus C.Nguni males versus N.Nguni males.
3. Sotho females versus C.Nguni females versus N.Nguni females.
4. Sotho males versus Sotho females.
5. C.Nguni males versus C.Nguni females.
6. N.Nguni males versus N.Nguni females.

B. *Whole sample comparisons*

7. White versus Black (males and females together).

8. White males versus Black males.

9. White females versus Black females.

10. White males versus White females.

11. Black males versus Black females.

C. *White - Tribal comparisons*

12. White versus Sotho (males and females combined).

13. White versus C.Nguni (males and females combined).

14. White versus N.Nguni (males and females combined).

15. White males versus Sotho males.

16. White males versus C.Nguni males.

17. White males versus N.Nguni males.

18. White females versus Sotho females.

19. White females versus C.Nguni females.

20. White females versus N.Nguni females.

CHAPTER 4

NUMERICAL VARIATION OF THE CERVICAL COLUMN

A. Number of Cervical Vertebrae in S.A. Black and White Samples (Table 4)

The number of cervical vertebrae for each skeleton was examined in the Sotho, the C.Nguni and the N.Nguni subgroups of the S.A. black series, the combined S.A. black sample and the S.A. white sample (Table 4). The modal number of seven cervical vertebrae was present in all samples, save for C.Nguni males where the seventh cervical vertebra was absent in one individual (2.0%). The frequency for a reduction to six cervical vertebrae in the combined male plus female C.Nguni sample was thus 1.0% and in the combined black male sample 0.6%. In the total male plus female black sample it was 0.3%. There was no statistically significant difference for a reduction in cervical vertebrae among the male tribal groups or between black and white males, nor in these groups for total males plus females. In none of the columns studied was there an increase in the number of cervical vertebrae.

Table 4: Number of Cervical Vertebrae in the S.A. Black and White Samples

			REDUCTION TO SIX CERVICAL VERTEBRAE					
	TOTAL		Male		Female		Male + Female	
	Male	Female	n	%	n	%	n	%
Sotho	50	50	0	-	0	-	0	-
C.Nguni	50	50	1	2.0	0	-	1.0	1.0
N.Nguni	50	50	0	-	0	-	0	-
S.A. Black	150	150	1	0.6	0	-	1	0.3
S.A. White	50	50	0	-	0	-	0	-

n = number of skeletons

In the C.Nguni male skeleton in which the seventh cervical vertebra was absent, the following features were observed. The spinous process of C6 was long and club-like, a feature characteristic of C7. The transverse processes were large and presented with bipartite foramina transversaria. Bipartite

foramina are commonly present on C6. The sixth cervical vertebra was thus considered to be transitional since it presented features characteristic of both C6 and C7. There were 12 thoracic vertebrae in the column. The first thoracic vertebra showed the normal configuration of a complete circular superior articular facets for articulation with the first ribs and inferior demifacets for the second ribs.

B. Number of Cervical Vertebrae in Various Population Groups

Few workers have investigated the number of vertebrae in the cervical region only. Most have recorded numbers for the entire presacral column. It is possible, however, to extrapolate figures for cervical numbers from three sources available. Allbrook (1955) found a single skeleton with a reduction to six cervical vertebrae in 206 East African vertebral columns, a frequency of 0.49%. The sex of this individual was not recorded. Stewart (1932) found a single female with cervical reduction in 217 Eskimo vertebral columns, a frequency of 0.46%. Bornstein and Peterson (1966) found four skeletons with a reduction to six cervical vertebrae out of a total of 1 239 vertebral columns of American Negroes, Caucasoids and Mongoloids, a frequency of 0.32%. These three frequencies are similar to that of the present study for S.A. blacks (0.3%). None of these authors reported an increase in the number of cervical vertebrae.

A reduction to six cervical vertebrae is thus seen to be rare in all the population studies available to me and varies from 0.3% to 0.49%. The relatively high frequency of six cervical vertebrae in the C.Nguni male sample (2.0%) is not significant and is most likely owing to the small sample size (n = 50).

C. Sex Differences

There were no statistically significant differences in the number of cervical vertebrae between male and female skeletons for any of the groups of this study (Table 4). This result supports the contention of Willis (1923) that numerical variations are independent of sex. His study however, may not be reliable because of the small number of female skeletons in his series. Furthermore, the study was carried out on the thoraco-lumbar region and is not

strictly comparable to the present study. Bornstein and Peterson (1966) showed however, that males tend to have a higher frequency of 25 presacral vertebrae and females a higher frequency of 23 presacral vertebrae, a finding confirmed by de Beer Kaufman (1974) for S.A. blacks. Since the present study is on cervical vertebrae only and the rare finding of a reduction in cervical vertebrae, whilst in a male, is not statistically significant, the findings cannot be equated with those of Bornstein and Peterson (1966).

D. Discussion

The finding in the present study that a reduction in the number of cervical vertebrae is rare, is confirmed from a study of the literature. Wingate (1922) stated that numerical variation in the cervical region was very rare in any mammal, and added that this region was numerically one of the most constant in the entire vertebral column. The possible aetiological factors causing numerical vertebral variation have been examined by many workers. Because of the numerical stability of the cervical region, most of the literature however, focuses on the entire presacral column. This literature will be examined in the following discussion.

Bardeen (1904) in morphological and embryological studies on human adults and embryos, stated that "regional variation in the vertebral column is an inherited condition which makes itself manifest early in embryonic development". Kühne (1932 cited by Allbrook, 1955) used vertebral roentgenograms to study vertebral variations in many families and demonstrated a tendency for morphological variations to occur in the same direction in genetically related individuals. He proposed that cranial variation, that is, one in which the seventh cervical vertebra bears a cervical rib and where the first sacral segment is either partially or totally separated from the sacrum, is dominant over caudal variation. Caudal variation is one in which the twelfth rib is increased in size and the fifth lumbar segment is partially or totally fused with the sacrum. It was assumed by Kühne (1932 cited in Allbrook, 1955) that in early ontogeny, there is an equal potentiality for shifting of the intersegmental borders in either a cranial or caudal direction. As development proceeds he said, the shifting of the

intersegmental borders in a cranial or caudal direction is determined by the presence of inherited genes.

These findings were extended by Sawin, Gow and Muehlke (1967) who presented experimental evidence carried out on rabbits. They showed that variation at vertebral borders and of vertebral numbers (especially thoraco-lumbar vertebrae) can be influenced by one major gene and several modifying genes. Bornstein and Peterson (1966) in a study on three population groups sho[illegible] that in man, the factors of race and sex influence the expression of the genes for numerical vertebral variation and they suggested that the total (male plus female) incidence of variation in presacral vertebrae is a specific characteristic of any population group. This suggestion was supported by de Beer Kaufman (1974) for a S.A. black sample. The study of Bornstein and Peterson (1966) found that the American Negro sample differed from the American Caucasoid sample and from the Mongoloid sample with respect to the distribution of specific vertebral variants. The rare vertebral variant of a reduction in number of cervical vertebrae has not, however, been shown to be characteristic of any one population group. Furthermore, consideration of the *total* presacral column is more likely to reveal population differences than that of the cervical region only.

E. Summary and Conclusions

Numerical variation, in the form of a reduction in the number of cervical vertebrae to six is rare. It was present in only one male of the total black S.A. sample (0.3%). There were no significant intertribal, int[illegible]p or sex differences for a reduction in number of cervical vertebrae in [illegible] study. The possibility is discussed that numerical vertebral variation may indicate genetic differences among population groups. This evidence is however, based on total presacral vertebrae and the results of this study, which are based on cervical vertebrae only, are inconclusive.

CHAPTER 5

OCCIPITALIZATION OF THE ATLAS

A. Occipitalization of the Atlas in the S.A. Black and White Samples

Occipitalization of the atlas was not present in either the S.A. black or white samples.

B. Occipitalization of the Atlas in Other Human Populations

Occipitalization of the atlas has been observed in a number of skeletal specimens and has been described by McAlister (1893), Dwight (1906), and Le Double (1912). None of these studies however, give the frequency of this variation. The frequency of occipitalization of the atlas in Japanese was reported by Hasebe (1913) to be 1.0% in 800 skulls and 0.5% in nearly 4 000 European skeletons. Lanier (1939) found a single white American male presenting with occipitalization of the atlas in a total of 200 American black and white skeletons, thus giving a frequency of 0.5%. No significant racial differences were present between American blacks and whites in his study.

C. Discussion

In the developmental process by which the primitive cervical segments are formed, the three sclerotomes above the atlas participate in the formation of the occipital bone. Occasionally, a part or all of the atlas may become incorporated in the occipital bone with a resulting firm union between it and the atlas. Elliot Smith (1908) stated that most authors regarded congenital fusion of the atlas to the occipital bone as shortening of the vertebral column and a further stage of the evolutionary process. They therefore looked upon these anomalies as "progressive" modifications of the vertebral column. Rosenberg (1876 cited in McNally *et al.*, 1990) however, viewed the manifestation of an additional occipital vertebra cranial to the atlas as lengthening the vertebral column and, therefore "regressive" in nature.

Dwight (1906) in an attempt to harmonise this discrepancy, advanced the theory that these variations did not indicate progressive or regressive change in the direction of shortening or lengthening of the column but were the expression of variations about a mean, and that they were frequently accompanied by compensatory changes in other regions. Gladstone and Erichsen-

Powell (1915) agreed with this theory and supported it by describing a skeleton with a fusion of the atlas to the occipital bone and which also had bilateral cervical ribs. The presence of the cervical ribs, they said, lengthened the thoracic region at the expense of the cervical region, which was shortened to six. The partially liberated occipital vertebra in this skeleton could thus be regarded as a compensatory lengthening of the cervical region, but the fusion of the atlas negated this view. Thus, the cervical region was diminished in length in both directions; by the fusion of the atlas with the occipital bone at one end and the development of cervical ribs at the other end.

Gladstone and Erichsen-Powell (1915) further suggested that instead of the normal development of the diarthrodial joint between the superior articular facets of the atlas and the occipital condyles, the tissue binding the cartilages at the atlas and the occipital bone did not break down to form a diarthrodial joint. In this sense there may be an "arrest" of the normal development of the joint. They called this the "arrest of development" theory. Since the diarthrosed vertebra has the typical features of C1 and is only attached to the occiput by the tissue which will form the atlanto-occipital joint, the "arrest of development" theory is favoured.

Ludwig (1957) proposed that the atlas is best regarded as an isolated cranial bone, and that the ontogenetic craniovertebral boundary is between the atlas and the axis. This proposal, however, does not take into account the fact that the atlas, although an atypical cervical vertebra, develops from the same elements as a typical vertebra namely the centrum and neural arch. Furthermore, Ludwig (1957) proposed that the atlas is not a presacral vertebra. This is not the view of most workers who count the atlas as a presacral vertebra as does the present study.

D. Summary and Conclusions

Occipitalization of the atlas was not present in either the black or white S.A. samples of this study. Studies from the literature report frequencies of 0.5% and 1.0%. Occipitalization is thus a rare finding. A number of theories have been put forward to explain this variation. The one favoured by this study is the "arrest of development" theory by Gladstone and

Erichsen-Powell (1915). They suggested that the tissue present during development which binds the atlas and the occipital bone does not break down and there is resultant fusion between the two bones. This study suggests that the atlas even if occipitalized, be counted as a cervical vertebra.

CHAPTER 6

CERVICAL RIB

A. Cervical Rib in S.A. Black and White Samples (Table 5, Figures 10 and 11)

A cervical rib was present in 7 N.Nguni males (14.0%) and 2 females (4.0%) giving a frequency of 9.0% in the combined-sex sample. In the Sotho sample, 5 males (10.0%) and 2 females (4.0%) presented with cervical rib, a combined-sex frequency of 7.0%. In the C.Nguni subgroup, the only individuals with cervical ribs were both male (4.0%) and this gives a combined-sex frequency of 2.0% (Table 5 and Figure 10). The high frequencies in the combined-sex samples for N.Nguni and Sotho skeletons were significant when compared with the C.Nguni sample ($P<0,05$).

In the combined S.A. black sample, cervical rib was present in 14 males (9.3%) and four females (2.6%). A cervical rib was thus present in 18 (6.0%) out of a total of 300 skeletons in the combined S.A. black sample (Table 5 and Figure 11). In the S.A. white sample however, this trait was present in only one male (2.0%) and this gives a combined sex frequency of 1.0% out of a total of 100 skeletons (Table 5 and Figure 11). The difference in frequency of cervical rib between the S.A. black (6.0%) and white (1.0%) samples was significant ($P<0.05$). This difference (between the two major groups) was due to the influence of the N.Nguni and Sotho subgroups on the combined black sample, since these two tribal subgroups had significantly ($P<0.05$) higher frequencies (9.0% and 7.0% respectively) when compared to the S.A. white sample (1.0%).

Table 5: The Frequency of Cervical Rib in S.A. Black and White Samples

SAMPLE	PERCENTAGE FREQUENCY		
	MALE	FEMALE	MALE + FEMALE
Sotho	10.0	4.0	7.0
C.Nguni	4.0	-	2.0
N.Nguni	14.0	4.0	9.0
Total S.A. Black	9.3	2.6	6.0
Total S.A. White	2.0	-	1.0

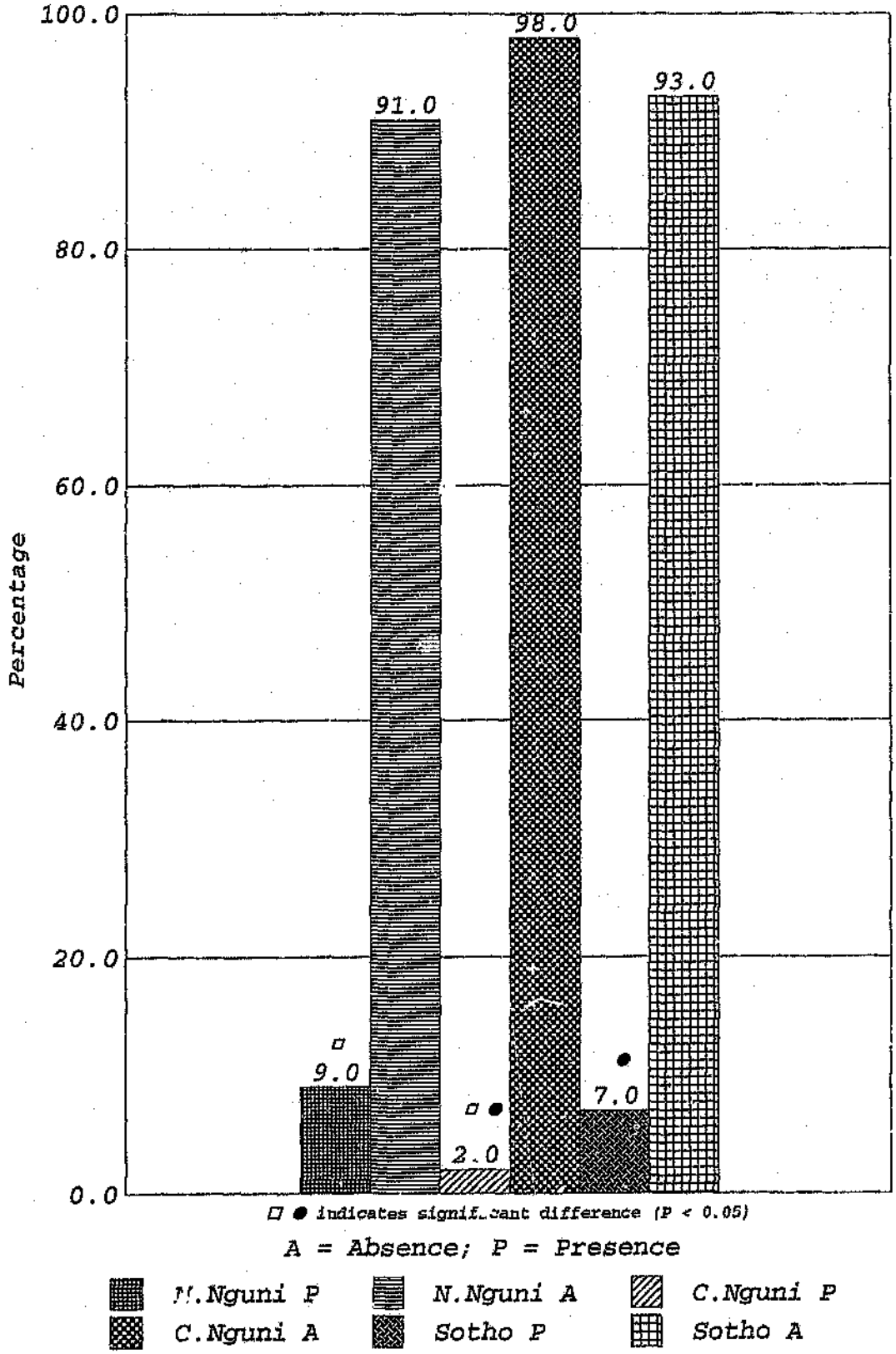

Fig. 10 The incidence of cervical rib in the N.Nguni, C.Nguni and Sotho tribal subgroups (males plus females combined).

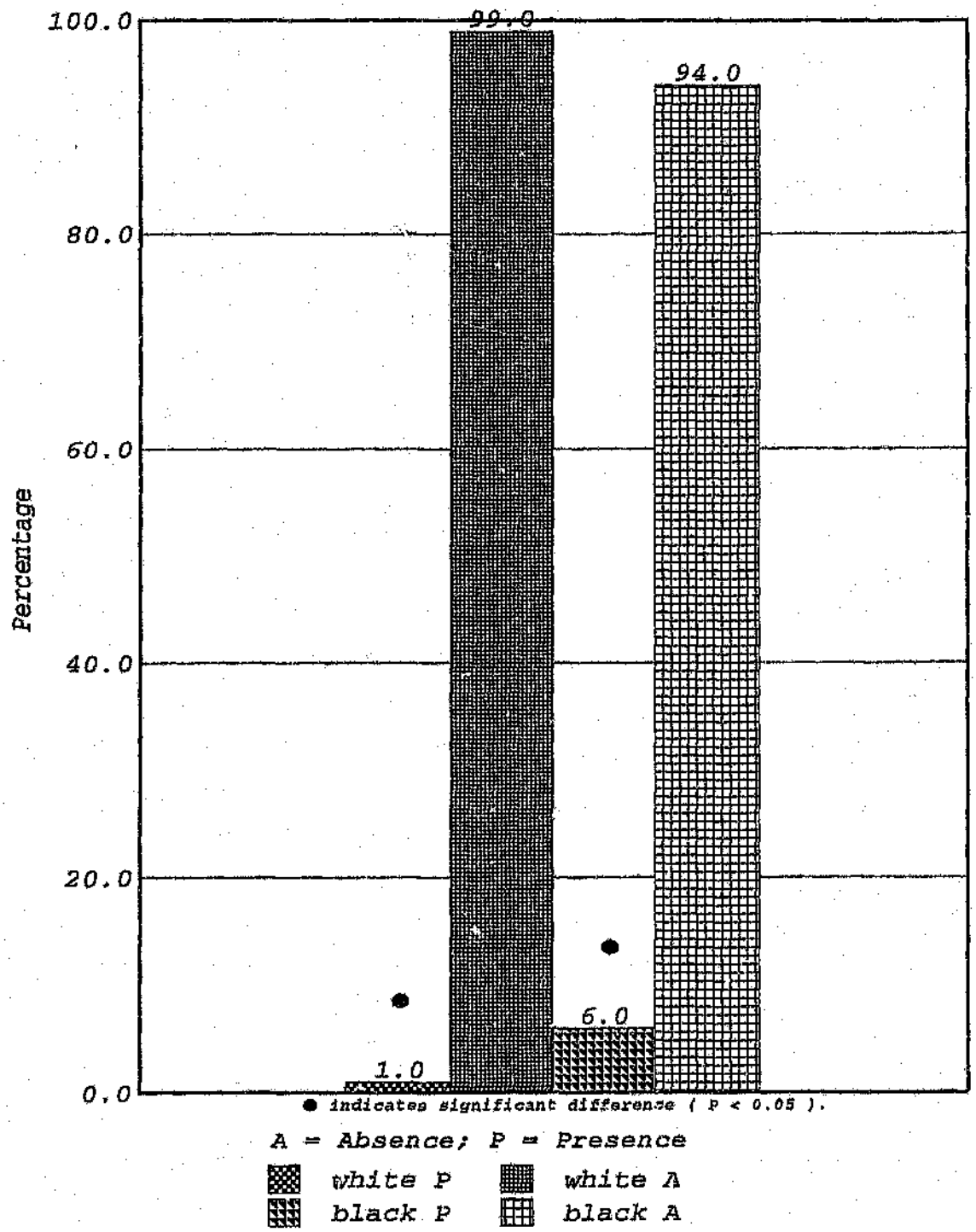

Fig. 11 The incidence of cervical rib in the total black and white S.A. samples.

B. Cervical Rib in Other Human Populations (Table 6)

In an early study on S.A. blacks, Shore (1930) found a frequency of cervical rib in 2.5% out of a total of 80 black vertebral columns. More recently, a radiographic study on a S.A. black sample by Asvat and Fell (1990) found 11 individuals (1.8%) with cervical rib out of a total of 622 radiographs studied. This finding is in contrast to the present study which shows a much higher incidence of this trait (6.0%) in black South Africans. The difference in frequency between the skeletal and radiographic studies was significant ($P<0.05$). It is possible that a small cervical rib (or one with fibrous components perhaps) did not show up on the radiographs. It is hoped to extend these studies to explore and possibly account for this apparent difference in frequency of cervical rib between the two black samples. A skeletal study by Allbrook (1955) on 206 East African blacks yielded a frequency of 0.5% for cervical rib. Thus, the frequency for cervical rib for blacks on the African continent in the studies available to me varies from 0.5% to 6.0%. A low frequency for American blacks (0.6%) was found by Lanier (1939) and is similar to that by Allbrook (1955) for East African blacks (0.5%). All studies discussed, save for that by Asvat and Fell (1990) were on skeletal material.

Table 6: Frequencies of Cervical Rib in Different Population Groups

	POPULATION	%	n
Black	S.A. black (present study)	6.0.	300
	(Asvat and Fell, 1990)*	1.8%	622
	(Shore, 1930)	2.5%	80
	East African black (Allbrook, 1955)	0.5%	206
	American black (Lanier, 1939)	0.6%	326
White	S.A. white (present study)	1.0%	100
	American white (Lanier, 1939)	1.7%	233
	White (Barbosa Suèira, 1933)	2.03%	1 527
	Japanese (Hasebe, 1912)	2.2%	181

n = number of skeletons/radiographs.

* = radiographic study.

The result for the frequency of cervical rib in whites was 1.0% for S.A. whites (present study) and 1.7% in American whites (Lanier, 1939). The occurrence of cervical ribs reported in the literature were summarised by Barbosa Suèira (1933) who reported that 31 cervical ribs (2.03%) were found in a total of 1 527 European skeletons. Hasebe (1912) found the variation in 2.2% of 181 Japanese skeletons. The results for white samples thus vary slightly from 1.0% to 2.03% and the differences among the groups are not significant. The Japanese have a slightly higher frequency (2.2%); the white/Japanese difference too, is not significant at the 5% level of significance.

In sum, the highest frequencies for cervical rib were found in the skeletal studies on S.A. blacks (present study 6.0%, Shore (1930) 2.5%). Lower frequencies were found in skeletal studies on whites and ranged from 1.0% (present study), 1.7% (American whites) to 2.03% (European skeletons).

C. Sex Differences

In the present study, black S.A. males showed a significantly ($P<0.05$) higher frequency of cervical ribs (9.3%) than females (2.6%). These findings are similar to findings of the radiographic study carried out by Asvat and Fell (1990) where black S.A. males (2.2%) showed a higher frequency than females (0.9%), though this difference was not statistically significant. The black American sample of Lanier (1939) consisted of 218 males of which one (0.46%) presented with the trait, and 108 females of which only one (0.9%) showed this variation. In summary, there is a general tendency for there to be more males than females with cervical rib in the black populations available to me.

The only S.A. white in the present study to exhibit a cervical rib was also a male. In contrast, in the white American sample of Lanier (1939), which consisted of 132 males and 101 females, not one male presented with the variation but four females (3.96%) had cervical ribs.

Honeij (1920), after reviewing the literature on a variety of European populations, between the years 1894 and 1918 found that out of a total of 200 skeletons with cervical rib, females were affected in 70.8% and males in 29.2% of skeletons with cervical rib. Keen (1907) studied 41 skeletons (racial

group not stated) with cervical ribs and the condition was present in 75.6% of females and 24.4% of males. Comparable figures for S.A. blacks give a male preponderance of 77.8%.

In sum the results for the frequency of cervical rib in S.A. blacks of the present study and those of a previous study (Asvat and Fell 1990) show that the trait occurs more frequently in black males than in females. This is in contrast to the findings in the study of Lanier (1939) on American whites and to the European study of Honeij (1920) where cervical rib occurred more frequently in females. It is possible that the male preponderance of cervical rib in blacks may signify a population difference and further studies are needed to substantiate this possibility.

D. Bilaterality and Unilaterality of Cervical Rib (Table 7)

In the S.A. black sample, 13 skeletons had bilateral cervical ribs (72.2%) and 5, unilateral right cervical ribs (27.8%). This difference was significant ($P<0.05$). There were no individuals with the unilateral left condition.

In the S.A. white sample, only one skeleton presented with the condition of cervical rib and it was bilateral.

In the radiographic study carried out by Asvat and Fell (1990), the bilateral occurrence of cervical ribs in S.A. blacks was, as with the present study the most common (72.7% - 8 individuals) and the unilateral right-sided cervical rib was present in only two individuals (18.2%). The unilateral left condition presented in but one individual (9.1%).

The preponderance of bilateral (as opposed to unilateral) cervical ribs is in agreement with the findings of Tilmann (1908 cited in Honeij, 1920) who reported that 67% of cervical ribs occurred bilaterally in 80% of individuals who had the condition of cervical rib. Keen (1907) reported that cervical ribs occurred bilaterally in approximately two-thirds of his sample of skeletons.

Thus the findings of the present study that bilateral cervical ribs were present in over two-thirds of S.A. blacks is in agreement with comparable studies in the literature.

Table 7: The Number of Bilateral or Unilateral Cervical Ribs in the S.A. Black and White Samples

	BILATERAL			UNILATERAL RIGHT			UNILATERAL LEFT		
	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL	MALE	FEMALE	TOTAL
Sotho	3	2	5	2	-	2	-	-	-
C.Nguni	2	-	2	-	-	-	-	-	-
N.Nguni	4	2	6	3	-	3	-	-	-
Total Black (N=300)	9	4	13	5	-	5	-	-	-
S.A. White (N=100)	1	-	1	-	-	-	-	-	-

E. Discussion

The literature was surveyed to examine the many theories put forward to account for cervical ribs. Early theories such as that by Rosenberg (1876 cited in McNally et *al.*, 1990) suggested that a decrease in the number of ribs was a manifestation of an ordered, evolutionary process. Rosenberg (1876 cited in Lanier, 1939) further suggested that the phylogenetic shortening of the rib-bearing segment of the vertebral column from its cranial and caudal ends, together with diminutive ribs on vertebrae 8 and 19 were indicative of a "progressive" evolutionary tendency. Furthermore, he interpreted large ribs on vertebrae 8 and 19 (ie. T1 and T12) as well as the presence of cervical and lumbar ribs to be "regressive" characteristics. Tredgold (1897) believed that additional ribs in cervical and lumbar regions were due to the persistence of a former condition and that a decrease in rib number was simply a part of that steady progressive change which had been seen to run right through the order of mammalia. He stated therefore, that a gradual but marked reduction in the total number of ribs takes place as man rises in the evolutionary scale. Tredgold (1897) published tables derived from other investigators which showed that in man, the eleventh and twelfth thoracic ribs were frequently rudimentary. In addition, he pointed out that in the chimpanzee, the twelfth and thirteenth ribs were poorly developed and, in the lemur, the thirteenth to the sixteenth (the latter being the last rib) were poorly developed. He thus attempted to show that as man ascended the evolutionary scale, the number of ribs became reduced. The presence of an extra rib, when present in man was, in his opinion, a regression in evolutionary advancement. Bardeen (1904)

and Dwight (1906) disagreed and suggested that variations were accidental and had no evolutionary significance.

Todd (1911) observed that the costal element of the seventh cervical vertebra, the precursor to a cervical rib, was normally present as a separate entity in the cervical region in the foetus. He suggested that it disappeared after birth, because it became incorporated by synostosis into the transverse process of the associated vertebra. He believed that the persistence of a cervical rib was caused by an interference in absorption of the costal element in the transverse process. McNally et al. (1990) confirmed that a separate centre for the costal element in C7 can be identified in up to 70% of foetuses from as early as 14 weeks of intra-uterine life. In 30% of the foetuses, no such separate centre could be identified. Alternatively, he postulated that the disappearance of the cervical rib on the seventh cervical vertebra may be due to pressure of nerves and vessels and consequently atrophy of the compressed tissue. Jones (1913) noted that when there was a large contribution to the brachial plexus from the second thoracic root, a rudimentary first thoracic rib resulted. Conversely he suggested that, where there is a limited contribution from the first thoracic root, cervical ribs were often present. He found some support for this theory in dissecting room cadavers and suggested that prefixation of the brachial plexus (contributing roots from C4 - C8 rather than C5 - T1) allowed the seventh cervical rib to persist. Todd (1911) however, dissected many cadavers which showed a normal configuration of the brachial plexus in the presence of cervical ribs. He concluded that neural development alone was insufficient to account for the condition of the ribs, but might be a contributing factor. Two workers, Thompson (1908) and Weber (1912-13) reported a familial occurrence of cervical ribs and suggested that genetic factors may play a role in the expression of the trait.

There is thus no general agreement among workers on the origin of cervical ribs. The theories range from evolutionary (Tredgold, 1897), ontogenetic (Todd, 1911) to genetic (Thompson, 1908; Weber, 1912-1913). A study by Kühne (1932 cited in Allbrook, 1955) however, subscribes to a genetic basis for the trait. He proposed that the presence of a cervical rib on C7 was evidence of cranial variation. Furthermore, he demonstrated that there was

a tendency for morphological variations to occur in the same direction in genetically related individuals. His findings were extended by Sawin, Gow and Muehlke (1967) who showed that variation at vertebral borders can be influenced genetically (see full discussion, Chapter 4 pp 26). Thus the significantly high frequency of cervical rib in the S.A. black sample as compared to the low frequency in the S.A. white sample suggests a possible genetic basis for this trait.

F. Summary and Conclusion

The high frequency of cervical rib in the S.A. black sample was owing to the high frequencies in the N.Nguni (9.0%) and Sotho (7.0%) tribal subgroups. These two subgroups showed a significant difference when compared to the frequency for the C.Nguni (2.0%). The combined black S.A. sample had a significantly higher frequency for cervical rib (6.0%) than that for the S.A. white sample (1.0%). It is suggested that this black/white difference may represent a possible population difference. The frequencies of cervical rib in two other studies on whites (1.7%, 2.03%) too, are lower than that for S.A. blacks.

The frequencies of cervical ribs in skeletal studies in the present S.A. black sample (6.0%) as well as that of Shores' (1930) were higher than those in two other black populations (East African black 0.5%, American black 0.6%). It is suggested that further skeletal and radiographic studies are needed to investigate and extend these findings.

Black S.A. males showed a higher frequency of cervical rib than females and this sex difference was significant.

Bilateral cervical ribs in S.A. blacks occurred significantly more frequently (72.2%) than a unilateral right or left rib (27.8%). This finding is in accord with results reported in the literature.

CHAPTER 7

SPINA BIFIDA OCCULTA OF THE CERVICAL AND CERVICO-THORACIC REGION

A. Spina Bifida Occulta in the S.A. Black and White Samples

(Table 8, Figures 12 and 13)

The results give the combined frequency for spina bifida occulta of all cervical vertebrae including the atlas and the vertebrae at the cervico-thoracic junction.

1. *South African Blacks*

The Sotho tribal subgroup presented the highest frequency of spina bifida occulta (7.0%), followed by the C.Nguni (4.0%). The lowest frequency was in the N.Nguni (2.0%) (Table 8, Figure 12). There were however, no significant differences among these subgroups. In the combined black S.A. African sample, 13 vertebral columns were affected, a frequency of 4.3% (Table 8, Figure 13).

Table 8: The Frequency of Cervico-Thoracic Spina Bifida Occulta and Spina Bifida of the Atlas in S.A. Black and White Samples

SAMPLE		MALE	FEMALE	MALE + FEMALE	
	n	%	%	n	%
Sotho	100	8.0	6.0	7	7.0
C.Nguni	100	-	8.0	4	4.0
N.Nguni	100	2.0	2.0	2	2.0
Total S.A. Black	300	3.3	5.3	13	4.3
Total S.A. White	100	2.0	8.0	5	5.0

2. *South African Whites*

Spina bifida occulta was present in five vertebral columns, giving a frequency of 5.0% in the white sample (Figure 13).

The S.A. black (4.3%) and white (5.0%) samples showed no statistically significant difference for the frequency of spina bifida occulta. In summary, no significant intertribal or intergroup differences were found for the frequency of spina bifida occulta when the total cervical and cervico-thoracic vertebrae were examined.

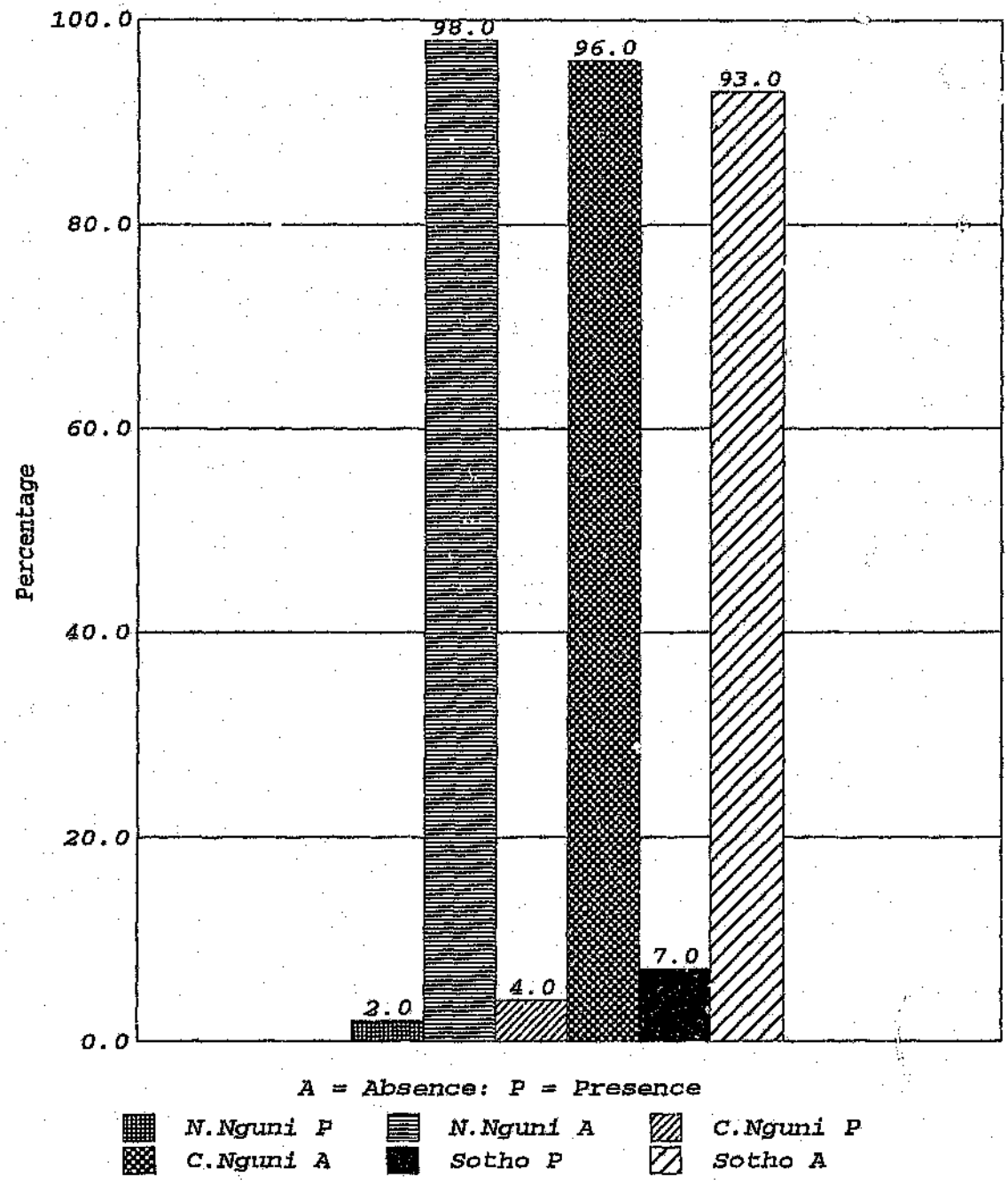

Fig. 12 The incidence of cervico-thoracic spina bifida occulta and spina bifida of the atlas in the N.Nguni, C.Nguni and Sotho tribal subgroups (Males plus females combined).

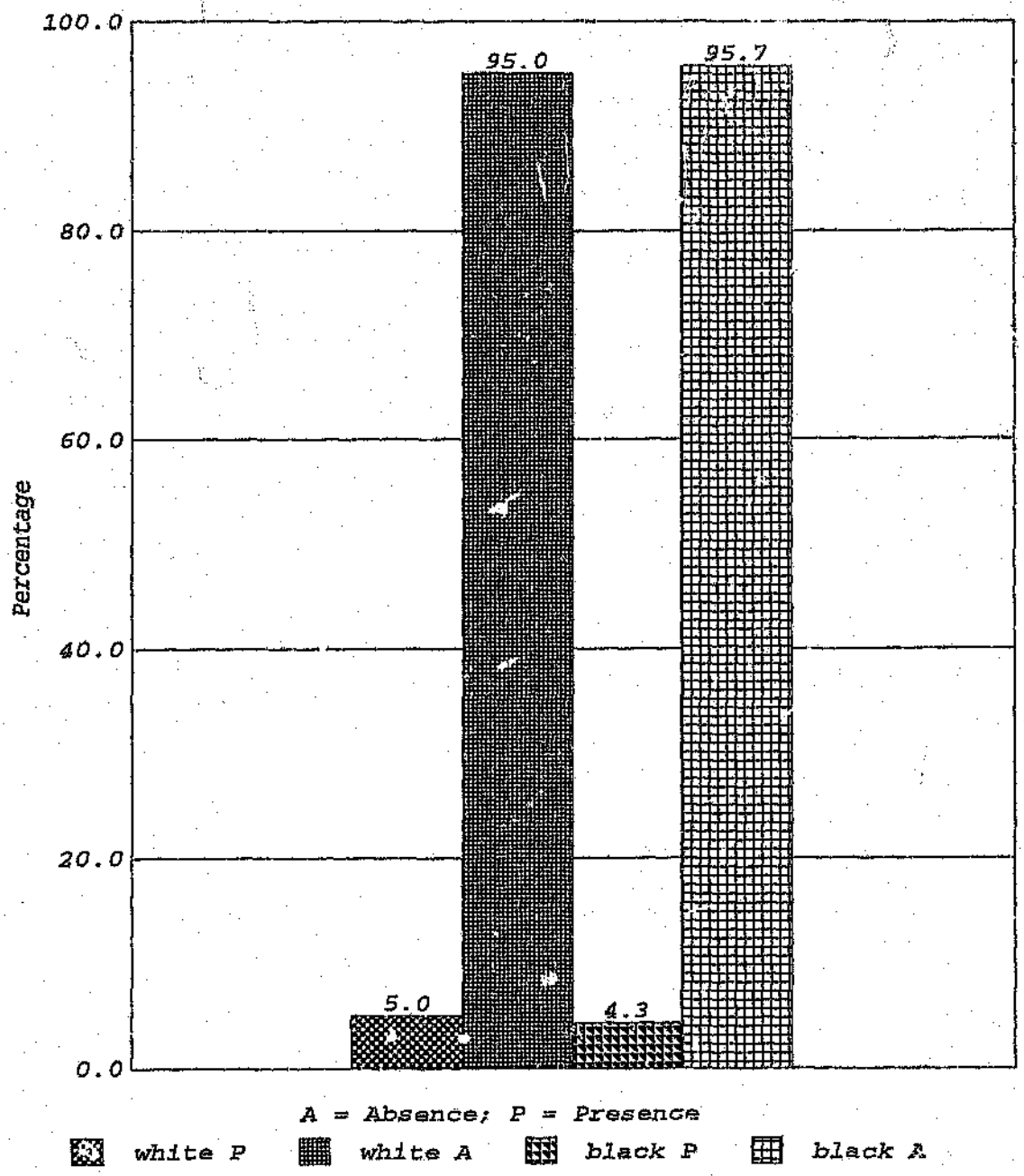

Fig. 13 The incidence of cervico-thoracic spina bifida occulta and spina bifida of the atlas in the total black and white S.A. samples.

3. *Vertebral Levels of Spina Bifida Occulta in S.A. Black and White Samples* (Tables 9 and 10)

Table 9 shows that in S.A. blacks, spina bifida occulta was present more often in the atlas (9 out of 13 affected columns) than at other levels. In eight columns, the atlas was the only vertebra involved and in one column, the atlas together with C7 had the defect.

Less often, spina bifida occulta was present in T1 (3 out of 13 affected columns). In two of these columns it was the only vertebra affected and in one, the adjacent C7 and T2 were also affected. In this region only one column showed the defect in both C6 and C7.

Table 10 shows that in S.A. whites, spina bifida occulta was present most often in the atlas (4 out of 5 affected columns). In three of these columns the atlas was the sole vertebra involved and in one individual, four adjoining vertebrae, C1-C4, were affected. In the cervico-thoracic region, only one individual showed spina bifida occulta and it was present in C7 only.

In summary, in both black and white samples, spina bifida occulta was present most frequently in the atlas (blacks - 69.2% of affected columns; whites - 80.0% of affected columns) and it was usually the only vertebra affected. The defect was present less often in the cervico-thoracic region (blacks - 30.8% of affected columns; whites - 20.0% of affected columns) and in this region adjoining vertebrae were usually involved.

Thus, the vertebral level at which spina bifida occulta occurs is similar in both S.A. blacks and whites. It is noteworthy however, that it is present almost exclusively at transitional regions of the cervical spine namely, the occipito-cervical and cervico-thoracic regions.

Table 9: Vertebral Levels of Spina Bifida Occulta of the Atlas and the Cervico-Thoracic Region in 300 Black S.A. Skeletons

NUMBER OF VERTEBRAE AFFECTED	VERTEBRAL LEVEL	NUMBER OF MALES	NUMBER OF FEMALES	TOTAL MALES + FEMALES n=300
One	C1 T1	2 2	6 -	8 2
Two	C6, 7 C1, 7	- 1	1 -	1 1
Three	C7, T1, T2	-	1	1

Table 10: Vertebral Levels of Spina Bifida Occulta of the Atlas and the Cervico-Thoracic Region in 100 White S.A. Skeletons

NUMBER OF VERTEBRAE AFFECTED	VERTEBRAL LEVEL	MALES	FEMALES	TOTAL MALES + FEMALES n=100
One	C1 C7	1 -	2 1	3 1
Four	C1,2,3,4	-	1	1

4. *Sex Differences* (Table 8)

Table 8 shows that spina bifid occulta was present slightly more often in male (8.0%) than in female Sotho columns (6.0%) but with equal frequency in the N.Nguni series (2.0%). In the C.Nguni, however, there was a female preponderance (8.0%) and no male spines showed the defect (Table 8). This finding was significant ($P<0.05$). In view of the small sample sizes however, the subgroups were combined to present results for the combined black sample. Spina bifida occulta was present more often in S.A. black (5.3%) and S.A. white (8.0%) females than in males (3.3% - black and 2.0% - white). This difference was not, however, significant. Previous studies suggest that spina bifida occulta is more prevalent amongst females than males. Brocklehurst (1976) for example, recorded a male to female ratio of 0.77 to 1 and James (1979) recorded a ratio of 0.44:1. This female preponderance is confirmed in the present study where both black and white females showed a higher incidence than the black and white males. The male to female ratio in the white S.A. sample was 1:4 and in the black S.A. sample 0.625:1. Thus, the findings of the present study agree with findings in the literature.

B. Spina Bifida Occulta in Various Population Groups

The results are now separated into those with spina bifida occulta of the atlas only and those with spina bifida occulta of the remaining cervical column including the cervico-thoracic junction. The reason for the separation of data was that the majority of studies reported findings on the lower cervical and cervico-thoracic junction only whereas some studies reported on C1 only.

1. *Spina Bifida Occulta of the Atlas in Other Populations*

In the present study the frequency for spina bifida occulta of the atlas was 3.0% in the combined black sample and 4.0% in the white sample. Shore (1930) found spina bifida occulta of the atlas in four (4.9%) out of the total of 82 columns of S.A. Negroes. Allbrook (1955) found a frequency of 3.9% in an East African population. Lanier (1939) found spina bifida occulta of the atlas in 2.0% of black American males.

Thus the frequency of spina bifida occulta of the atlas in blacks is relatively high and ranges from 2.0% in American blacks to 3.0% and 4.9% in two S.A. black samples. The frequency in the S.A. white sample too is high, being 4.0%.

2. *Spina Bifida Occulta of Cervico-Thoracic Vertebrae (excluding the atlas) in Various Population Groups*

Table 11 gives the frequencies of spina bifida occulta of the cervico-thoracic vertebrae (excluding the atlas) in various populations.

(i) *Present Study*

The frequency in S.A. blacks of the present study is 1.7% and that in S.A. whites 1.0%. This difference was not statistically significant.

(ii) *Blacks/Negroes.*

The frequency of spina bifida occulta in blacks of various populations ranges from 1.7% (present study) to 3.6% (Shore, 1930). Both these studies were on S.A. blacks. A radiographic study on S.A. blacks by Levy and Freed (1973) reported a frequency of 2.49%. A skeletal study on East African Negroes by Allbrook (1955) yielded a frequency of 2.9%, whereas a radiographic study on East African Negroes by Whittaker (1957) found a slightly lower frequency of 1.3%. Cockshott (1958) reported a frequency of 2.2% in West African Negroes.

(iii) *Whites.*

The frequency in the relatively small S.A. white sample of the present study is 1.0% and is the highest in table 11 for whites. This result is in contrast to a radiographic study on S.A. whites by Asvat and Lazarus (1991)

Table 11: Cervico-Thoracic Spina Bifida Occulta in Various Population Groups* (modified from Levy and Freed, 1973)

AUTHOR	POPULATION STUDIED	MATERIAL	NUMBER STUDIED	VERTEBRAL LEVELS AFFECTED	SPINA BIFIDA OCCULTA %
Shore (1930)	South African Negroes	Skeletons	82	C7, T1, T2, T3	3.60
Allbrook (1955)	East African Negroes	Skeletons	206	C7, T1, T3	2.90
Whittaker (1957)	East African Negroes	Radiographs	1 226	C7, T1	1.30
Cockshott (1958)	West African Negroes	Radiographs	1 000	C7, T1, T2	2.20
Levy and Freed (1973)	South African Negroes	Radiographs	5 363	C6, C7, T1, T2, T3	2.49
Asvat (present study)	South African Blacks	Skeletons	300	C6, C7, T1, T2	1.70
Walker & Bucy (1934)	North American Whites	Radiographs	4 088	C3, C7, T1, T2, T3	0.02 - 0.10
Kerley (1950)	British Whites	Radiographs	10 000	---	0.16
Asvat & Lazarus (1991)	South African Whites	Radiographs	500	---	0.00
Asvat (present study)	South African Whites	Skeletons	100	C2, C3, C4, C7	1.00

* The data is from workers who give results for spina bifida occulta of the cervico-thoracic region excluding the atlas.

where no individuals were found with spina bifida occulta in a sample of 500 radiographs.

A low frequency in whites is reported in several large radiographic studies on North Americans and ranges from 0.02% to 0.1% (Walker and Bucy, 1934). In another study on British whites by Kerley (1950) where 10 000 radiographs were examined the frequency too, was low (0.16%).

Whites, in general, thus have a uniformly low frequency of spina bifida occulta whereas all black groups have a higher frequency of the defect.

An explanation is sought for the conflicting results in S.A. whites (present study 1.0%; radiographic study of Asvat and Lazarus (1991), 0.0%). Since the radiographic sample was relatively small (n = 500) when compared with that for example, of Kerley (1950) where 10 000 radiographs were examined, it is possible that evidence of spina bifida occulta would be found in a larger radiographic sample of S.A. whites. Furthermore, even though a radiologist was consulted on interpretation of the radiographs by Asvat and Fell (1990), it is not impossible that evidence of the defect in the form of a narrow cleft (as present in Fig. 3) was missed on the radiographs.

This probability is strengthened by the findings of a relatively high frequency in the present S.A. white <u>skeletal</u> study (1.0%) in which vertebrae are subjected to individual scrutiny.

It is notable that the low frequencies for whites are all based on radiographic studies save for the sole relatively high frequency in the present <u>skeletal</u> study of S.A. whites. In addition, The S.A. white sample is small (n=100) whereas the various studies from the literature number in the thousands (the sole finding of a relatively high frequency of the defect in the present white skeletal sample will be investigated in a larger sample). Sample size too, may account for the relatively low frequency (1.7%) in the present black sample (n=300) when compared with the large radiographic study (n=5363) of Levy and Freed (1973). In the latter, the frequency was 2.49%. It is intended to extend the study on S.A. blacks to provide a larger sample.

F. Discussion

The term spina bifida refers to a number of defects of the vertebral arch where the two halves fail to develop fully. These range from spina bifida

occulta, which is an unfused posterior arch, to abnormalities that involve the spinal cord and its meninges such as meningomyelocele and myelocele. The latter are classed in general terms as spina bifida aperta. Most of the work on the aetiology of spina bifida has been done on spina bifida aperta. The present study was concerned with spina bifida occulta in which there is only a bony defect in the posterior arch. Since this produces no symptoms it is not diagnosed clinically and little work has been done on its aetiology. However, since the defects are part of a range of related developmental defects of the vertebral column, it was considered justifiable to present possible aetiological causes, most of which are based on studies made on groups or individuals with spina bifida aperta. These results are extrapolated where possible for spina bifida occulta.

The possible causes of spina bifida aperta have been sought for by many workers. All researchers agree that a combination of genetic and environmental influences are responsible for the occurrence and severity of this defect. Influences such as population group, sex and family history fall under genetic aetiology whereas time, place and parental circumstances are grouped with environmental influences (Leck, 1974; Janerich, 1974).

Population Variation

Leck (1974) states that the natural incidence of spina bifida varies between different races, religion and culture and he suggests that these factors play a major role in maintaining this variation. Analysis of results in black and white population groups for the frequency of spina bifida *occulta* shows that blacks, on the whole, have a higher frequency than whites (Table 11). This supports Leck's (1974) finding on spina bifida aperta that frequency varies between different races and suggests a link between the etiology of spina bifida occulta and aperta.

Genetic Epidemiology of Spina Bifida

When comparing the occurrence of spina bifida in twins and single siblings, Leck (1974), reported an increased recurrence rate among sibships. In addition, the concordance rate of spina bifida in twins was higher among monozygotic twins than dizygotic twins (Janerich, 1974; Leck, 1974). The recurrence of spina bifida within an affected family was also higher than in

the general population (Janerich, 1974; Nevin *et al.*, 1981). These findings give support for the genetic basis of spina bifida aperta, and possibly, for spina bifida occulta if the results are extrapolated for the lesser defect.

There are a variety of other causes implicated in spina bifida aperta. These include seasonal variation (Brocklehurst, 1976; Maclean and Macleod, 1984), socio-economic class (Emanual, 1922; Nevin *et al.*, 1981) and maternal factors such as age and parity (Elwood, 1976) and blood group (1975 McKeown and Record cited in Leck, 1977). With regard to the present study the most important may be a genetic factor. It is tentatively suggested that the relatively high frequencies of spina bifida occulta found in black samples as compared with whites may be characteristic of blacks in general and that genetic factors play a part in the expression of this bony defect.

Vertebral Levels of Spina Bifida Occulta

An explanation was sought for the higher frequency of spina bifida occulta in the atlas than in succeeding vertebrae. Examination of ossification in the vertebral column reveals that the atlas may differ in its pattern of ossification from typical cervical vertebrae. The spinous processes in typical cervical vertebrae are ossified from two centres which appear in the vertebral arch and spread backwards into the laminae. They then fuse to form the spinous process. In the atlas, centres similarly appear in the lateral masses, extend into the posterior arch and unite. However, according to Williams *et al.*, (1989), they may unite directly or "through the medium of a separate centre." This alternative pattern of a separate midline ossification centre in the atlas may well be a factor in the relatively high frequency of non-fusion of the posterior arch (and thereby spina bifida occulta) of the atlas.

Another developmental factor which might be involved in differing frequencies of spina bifida occulta at different vertebral levels may be the potential for variation which is present in all transitional regions of the vertebral column (and this variation is, indeed, the subject of many reports). It was found (Tables 9 and 10) that spina bifida occulta was present only at the transitional regions of the cervical column, that is, the occipito-cervical and cervico-thoracic junctional areas (indeed, spina bifida is

characteristically found at the succeeding thoraco-lumbar and lumbo-sacral junctional areas).

The occipito-cervical junctional area is however, unique in that it is bounded cranially, not by vertebrae, but by the occipital bone. During development, a series of mesodermal somites provide the tissue from which the vertebral column is derived. The somites cranial to the position of the potential atlas however, are different from the potential vertebral somites in that they are destined to form part of the occipital bone. They are termed occipital somites.

The potential for variation which is present in all junctional areas of the vertebral column, in the occipito-cervical region is thus subject to an additional influence, that of the occipital bone which may contribute to the possibility of increased variability.

Evidence of the influence occipital somites may have on the atlas is seen in the occasional report of occipitalization of the atlas.

In more general terms, the absence of a spinous process which provides strength and stability in the atlas, may render the atlas more susceptible to the formation of spina bifida occulta.

G. Summary and Conclusions

The frequency of spina bifida occulta in all cervical vertebrae (including the atlas and vertebrae in the cervico-thoracic region) was 4.3% in black South Africans and 5.0% in white South Africans. When the results were separated according to the level of occurrence of spina bifida occulta, the atlas was the vertebra most frequently affected in both S.A. black(3.0%) and white (4.0%) groups. Similar relatively high frequencies were reported in another two black groups; South African Negroes (4.9%) and East African Negroes (3.9%).

The frequencies of the defect in the cervico-thoracic region (with exclusion of results on the atlas) were 1.7% in black and 1.0% in white South Africans. Two comparable studies on the cervico-thoracic region on S.A. blacks yielded frequencies of 3.6% (Shore, 1930) and 2.49% (Levy and Freed, 1973). Studies on other black groups range from 1.3% (a radiographic study)

and 2.9% (a skeletal study) in East Africans, to 2.2% in West Africans. In sum, frequencies for blacks in skeletal studies range from 1.7% to 3.6%.

Frequencies in white groups from large radiographic studies are lower and range from 0.02% to 0.16%. The highest frequency for whites was found in the present study (1.0%). It is tentatively suggested that the results of the white skeletal study may be influenced by the small sample size and that a larger sample might yield a lower frequency more in line with results for other white groups. A tentative suggestion is also put forward that some radiographic studies might fail to detect a vertebra with a *narrow* cleft in the vertebral arch. This might suggest a possible explanation for the zero frequency of the defect in the white radiographic study by Asvat and Lazarus (1991).

Females presented with a higher incidence of spina bifida occulta than males in both black and white samples of the present study and this tendency confirms findings in the literature.

With regard to the level of spina bifida occulta, the atlas vertebrae was the vertebra most affected in both the black and white South African samples and this was followed by the defect in vertebrae at the cervico-thoracic region. The defect thus occurs most frequently at transitional regions of the vertebral column. It is tentatively suggested that the occipito-cervical region may be more vulnerable than the cervico-thoracic region to influences which could contribute to variation in vertebrae in general and specifically to spina bifida occulta. These factors include a) the absence of a spinous process, b) variation in the pattern of ossification of the posterior arch of the atlas and c) the proximity of the atlas to the occipital somites which will develop into the basiocciput.

The causal factors for spina bifida are numerous, but the general consensus of opinion is that genetic and environmental influences combine to cause spina bifida aperta. The present study confirms reports that spina bifida occulta is present more frequently in black than in white population groups. It is thus suggested that genetic factors play a part in the etiology of spina bifida occulta.

CHAPTER 8

CONFIGURATION OF SPINOUS PROCESSES IN CERVICAL VERTEBRAE C2 TO C7

A. Configuration of Cervical Spinous Processes in the S.A. Black and White Samples.

A preliminary analysis of numbers of spinous processes in males and females showed minimal differences. Thus separate data for the sexes are not given.

A1. *Bifid Cervical Spinous Processes* (Tables 12 and 13)

In the black S.A. sample, bifid cervical spinous processes were present in 546 cervical vertebrae. This gives a frequency of 31.6% out of a total of 1 729 spinous processes (Table 12). A bifid spinous process occurred most commonly in the axis vertebra and was present in 251 out 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%). There is thus a decreasing order of bifidity from C2-6.

In the white S.A. sample of 586 vertebrae, 345 (58.9%) had bifid spinous processes (Table 12) and this frequency was significantly higher ($P<0.05$) than that in S.A. 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 decreasing order of bifidity was similar to that for blacks. The higher frequency in the S.A. white sample was a result of the significantly higher frequencies of bifidity in ($P<0.05$) C3, C4, C5 and C6 when compared with the corresponding vertebrae in the S.A. black sample.

The bifid spinous processes were subdivided into bifurcate (divergent alae) and cleft (parallel or non-divergent alae) (Table 13). In the S.A. black sample, the bifurcate type of spinous process was present significantly more often (60.8%) than the cleft type (39.2%). In the white sample the bifurcate type was present more often (79.4%) than the cleft type (20.6%) and this difference too was significant ($P<0.05$). When the individual vertebrae were analysed in blacks, the axis presented with a significantly ($P<0.05$) higher frequency of the bifurcate type (86.5%) as opposed to the cleft type (13.5%). Cervical vertebrae three through six however, showed a higher

incidence of the cleft type, though this difference was not statistically significant. In the white S.A. sample the bifurcate type of spinous process occurred more frequently in all cervical vertebrae, C2-C7 inclusive (Table 13). Though the preponderance of cleft spinous processes in C3 to C6 in the black sample was not significant, the finding may be a characteristic of black cervical vertebrae.

Table 12: Numbers of Bifid and non-Bifid Cervical Spinous Processes in the S.A. Black and White Samples

		VERTEBRA							
		C2	C3	C4	C5	C6	C7	TOTAL	%
White	Bifid	89	57	79	78	40	2	345	58.9
	Non-Bifid	11	39	21	16	56	98	241	41.1
	TOTAL	100	96	100	94	96	100	586	
Black	Bifid	251	60	79	104	51	1	546	31.6
	Non-Bifid	49	219	207	185	240	283	1 183	68.4
	TOTAL	300	279	286	289	291	284	1 729	

Table 13: Numbers of Bifurcate and Cleft Cervical Spinous Processes in Total Bifid Spinous Processes of S.A. Black and White Samples

		VERTEBRA							
		C2	C3	C4	C5	C6	C7	TOTAL	%
White	Bifurcate	70	51	66	58	27	2	274	79.4
	Cleft	19	6	13	20	13	0	71	20.6
	TOTAL BIFID	89	57	79	78	40	2	345	
Black	Bifurcate	217	25	31	39	19	1	332	60.8
	Cleft	34	35	48	65	32	0	214	39.2
	TOTAL BIFID	251	70	79	104	51	1	546	

A2. *Non-Bifid Cervical Spinous Processes* (Tables 12, 14 and 15)

The results for non-bifid cervical spinous processes in the three tribal subgroups are given in Table 14. The results for the pooled black sample are given in Table 15. Table 12 shows that in the combined S.A. black sample, the non-bifid cervical spinous processes were present more frequently (68.4%) than

the bifid type (31.6%). In the S.A. white sample the position was reversed with the bifid type having a higher frequency (58.9%) as opposed to the non-bifid type (41.1%).

The non-bifid spinous processes were considered in four subclasses - acinate, obtuse, pediculate and clavate (Fig. 5, p. 15). In all three tribal subgroups, the clavate type of spinous process was the most common. It was 42.6% in the N.Nguni, 41.1% in the Sotho and 39.0% in the C.Nguni. This was followed by the pediculate type, with the N.Nguni again showing the highest frequency (40.8%), followed by the C.Nguni (34.6%) and the Sotho (29.7%). The obtuse type was present less frequently in both the C.Nguni (13.6%) and N.Nguni (13.2%) subgroups. The lowest frequencies in the table were for the acinate type in the C.Nguni (12.8%) and 3.4% in the N.Nguni and for the obtuse type (10.3%) in the Sotho. The acinate type was however, the third highest in the Sotho subgroup (18.9%).

In the combined S.A. black sample (Table 15) the predominant type of non-bifid cervical spinous process was the clavate (40.8%), followed by the pediculate type (34.7%,. the obtuse type (13.3%) and lastly the acinate type (12.1%). In the S.A. 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%). 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 common. The predominance of the clavate subtype was owing in part to the finding that all seventh cervical vertebrae (in both black and white samples) were of the clavate subtype.

The findings in the present S.A. black sample of predominantly clavate spinous process, differs from Shore's (1931) finding that the pediculate type was predominant in his black S.A. sample, followed by the clavate. In a San sample studied by Shore (1931), the clavate type was found to be the predominant type followed by the pediculate type. This corresponds with results in the black sample of the present study.

The results of the present study show no significant differences among the four subtypes of non-bifid cervical spinous processes between black and

Table 14: Numbers of Non-Bifid Cervical Spinous Processes in the Three Black Tribal Samples

		VERTEBRAE							
		C2	C3	C4	C5	C6	C7	TOTAL	%
C.Nguni	Acinate	3	16	17	9	7	0	52	12.8
	Obtuse	9	5	9	21	11	0	55	13.6
	Pediculate	0	59	46	29	6	0	140	34.6
	Clavate	0	0	0	5	60	93	158	39.0
	TOTAL	12	80	72	64	84	93	405	
Sotho	Acinate	4	29	26	16	4	0	79	18.9
	Obtuse	6	6	10	17	4	0	43	10.3
	Pediculate	0	45	42	35	2	0	124	29.7
	Clavate	0	0	0	0	75	93	172	41.1
	TOTAL	10	80	78	68	85	93	418	
N.Nguni	Acinate	0	4	2	5	1	0	12	3.4
	Obtuse	12	10	8	8	9	0	47	13.2
	Pediculate	3	46	47	36	13	0	145	40.8
	Clavate	0	0	0	0	58	97	151	42.6
	TOTAL	15	60	57	49	81	97	355	

Table 15: Non-Bifid Cervical Spinous Processes in the combined S.A. black and white samples

		VERTEBRAE							
		C2	C3	C4	C5	C6	C7	TOTAL	%
Black	Acinate	7	49	45	30	12	0	143	12.1
	Obtuse	27	21	27	46	24	0	145	13.3
	Pediculate	3	150	135	100	21	0	409	34.7
	Clavate	0	0	0	5	193	283	481	40.8
	TOTAL	37	220	207	181	250	283	1 178	
White	Acinate	0	7	4	1	3	0	15	6.2
	Obtuse	8	16	10	5	1	0	40	16.5
	Pediculate	3	16	9	7	1	0	36	14.8
	Clavate	0	0	0	3	51	98	152	62.5
	TOTAL	11	39	23	16	56	98	243	

white samples. There is thus no indication of a population difference between the black and white samples in this regard.

B. Discussion

Cunningham's Textbook of Anatomy (Romanes, 1991) 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 (1915 cited by Shore, 1931) 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 than in Europeans, and, as a rule, are simple (that is non-bifid). He notes further that the only cervical vertebra which presents a bifid spine in all races is the axis and that even this may be non-bifid in the Negro, and occasionally in the European. The present study is generally in agreement with these statements since S.A. white cervical spinous processes are significantly more bifid (58.9%) than non-bifid (41.1%) whereas non-bifidity is significantly more frequent in S.A. blacks (68.4%). Furthermore, the present study also confirmed that the axis consistently displayed the bifid character in most individuals in both black (83.7%) and white samples (89.0%).

Shore (1931) studied the configuration of spinous processes in samples of S.A. black and white populations. The incidence of bifidity and non-bifidity in his white sample was 71.6% and 28.3% respectively. In the present study, the white S.A. sample too showed a higher frequency of bifid spinous processes (58.9%) as compared with non-bifid (41.1%).

Shores' (1931) black sample however, had a high frequency for non-bifid spinous processes (78.8%). This was even higher than that of the present study (68.4%). A trend is thus shown towards non-bifidity in both black samples.

The finding that bifid cervical spinous processes occur almost two times more frequently in the white S.A. sample (58.9%) than in the black S.A. sample (31.6%) of the present study as well as in Shore's (1931) study (71.6% as

compared with 28.3%) may suggest a population difference with regard to this trait.

Von Eggeling (1922 cited by Shore, 1931) made extensive comparative studies of the skeleton and the muscular systems of man, anthropoids and monkeys and suggested that variations in the bifidity of the cervical spinous processes depend on posture and mobility of the cervical spine. The non-bifid character of the cervical spinous processes which he found in 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 non-bifid cervical spinous processes to the lesser degree of development of the semispinalis cervicis muscle in spines of lesser mobility.

Von Eggeling (1922 cited by Shore, 1931) also made a developmental study of bifidity. He observed that the "bifid" condition of the cervical spinous processes could be recognised in the cartilaginous stage of development. He also observed that some of the commonly non-bifid 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 at the seventh and thence in a cranial direction. He thus suggested that the bifid quality of the cervical spinous processes in whites 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 the results in the white sample would seem to indicate that the change of type of the cervical spinous processes indicated during development, i.e. bifid to non-bifid, has now attained virtual completion in the seventh vertebra, but has not attained an appreciable frequency in the middle members of the cervical column in the white sample. The black sample however, would seem to be the more stable in terms of von Eggelings findings; the cervical spinous processes have tended to retain their non-bifid character acquired during development. It is possible that there is a developmental explanation for the preponderance of non-bifid spines in C3-C7 of the S.A. black sample. This is supported by the finding of a preponderance of non-bifidity in Shore's (1931) S.A. black sample.

C. Summary and Conclusions

Bifid cervical spinous processes were present significantly more frequently in S.A. whites (58.9%) than in S.A. blacks (31.6%). A bifid spinous process occurred most commonly in the axis where the frequency in the white sample was 89.0% and slightly less (83.7%) in the black sample. In the white sample, the frequency was somewhat less in C5 (83.0%) and C4 (79.0%) than in C2 and fell to 59.4% in C3 and 41.7% in C6. A bifid spine was rare in C7 (2.0%). This accords in general with textbook statements that cervical vertebrae 2-6 have bifid spines whereas that of C7 is usually non-bifid. There is a similar order of decrease in bifidity in the S.A. black sample.

The bifurcate subtype of bifid spinous process (divergent alae) characterises the axis in both black and white samples and predominates in C3-C6 in the S.A. white sample. In the S.A. black sample however, the cleft type (parallel alae) predominates in C3-C6 and this finding may be characteristic of S.A. blacks.

Non-bifid cervical spinous processes were present significantly more frequently in S.A. blacks (68.4%) than in whites (41.1%). These findings were in agreement with those of Shore (1931) on S.A. blacks. It is postulated that this relatively high frequency of non-bifid spinous processes in both S.A. black studies as compared with S.A. whites may suggest a population difference. When the non-bifid spines were subdivided into acinate, obtuse, pediculate and clavate, the clavate subtype was the most common in both groups (black - 40.8%, white - 62.5%) and the acinate the least common (black - 12.1%, white - 6.2%). It is noteworthy that the spines of C7 were always of the clavate subtype.

Von Eggeling (1922 cited in Shore, 1931) presented evidence that there was a developmental progression from bifidity in the foetal stage towards non-bifidity in the first year of life and progressing up to puberty. This developmental hypothesis could possibly account for the relatively high frequency of non-bifid spinous processes in black samples; the black spinous processes have thus tended to retain the non-bifid character acquired during development. Von Eggeling (cited in Shore, 1931) suggested that the relatively high frequency of bifidity in whites was a regressive step in the evolution of bifidity. There could thus be a developmental explanation for the differing frequencies of bifidity found in black and white groups.

CHAPTER 9

BIPARTITE FORAMEN TRANSVERSARIUM

A. Bipartite Foramen Transversarium in the S.A. Black and White Samples (Table 16, Figures 14 and 15)

Table 16: The Frequency of Bipartite Foramen Transversarium in S.A. Black and White Samples

SAMPLE	PERCENTAGE FREQUENCY			
	MALE	FEMALE	MALE + FEMALE	
	%	%	%	n
Sotho	54.0	44.0	49.0	100
C.Nguni	46.0	34.0	40.0	100
N.Nguni	32.0	22.0	27.0	100
TOTAL S.A. BLACK	44.0	18.7	31.3	300
TOTAL S.A. WHITE	52.0	60.0	56.0	100

The frequency of bipartite foramen transversarium in all cervical vertebrae in the tribal subgroups is given in Table 16 and Figure 14. The Sotho sample had the highest frequency of 49.0%, followed by the C.Nguni (40.0%) and N.Nguni (27.0%). The Sotho and C.Nguni samples presented with a statistically significantly ($P<0.05$) higher frequency of this trait when compared to the N.Nguni sample. The subgroups were combined to give a sample representative of S.A. blacks. The black sample (combined-sex data) showed a lower frequency of bipartite foramen transversarium (31.3%) than the white sample (56.0%) (Table 16, Figure 15). This difference was significant ($P<0.05$) and was mainly due to the white female sample which had a significantly ($P<0.05$) higher frequency (60.0%) than the black female sample (18.7%). White males too, had a higher frequency (52.0%) than black males (44.0%) but the difference was not significant.

The only other results in population studies available to us was that by Saunders (1978) who reported an exceptionally high frequency of 84.8% and 78.1% for Eskimo-Aleut males and females respectively.

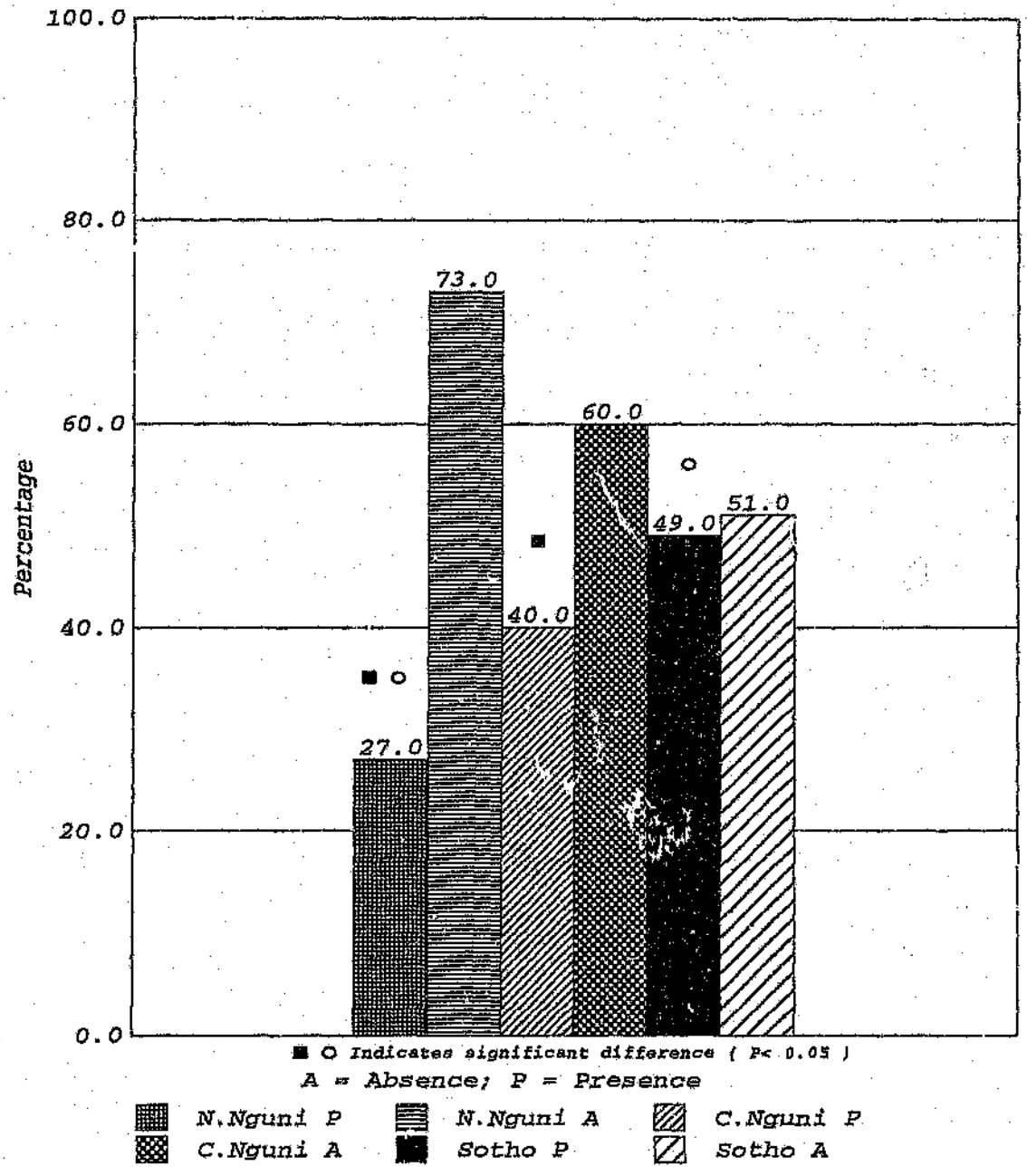

Fig. 14 The incidence of bipartite foramen transversarium in the N.Nguni, C.Nguni and Sotho tribal subgroups (males plus females combined).

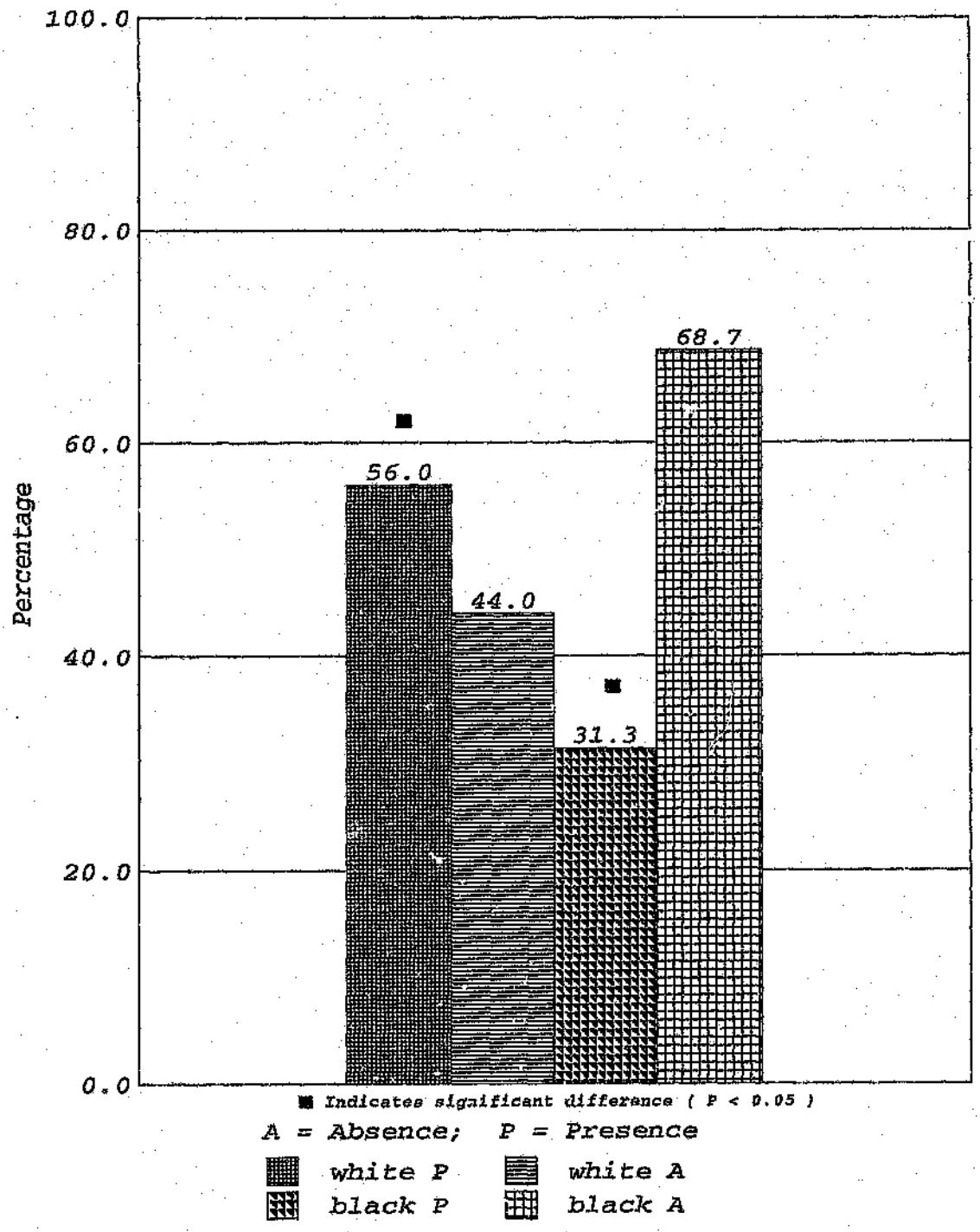

Fig. 15 The incidence of bipartite foramen transversarium in the total black and white S.A. samples.

Two other groups from her study are the Mobridge (males - 76.9%; females - 90.2%) and Libban samples (males - 89.2%; females - 81.0%) who both present with similarly high frequencies. These frequencies are far higher than those of the present study and require further investigation.

B. Sex Differences

None of the three tribal subgroups showed statistically significant sex differences, although bipartite foramen transversarium had a slight male preponderance in all three subgroups (Table 16). In the combined S.A. black sample, the males showed a higher frequency of this variation (44.0%) when compared to the black S.A. females (18.7%) and this difference was significant ($P<0.05$). No significant sex difference was present in the S.A. white sample though here there was a female preponderance (females 60.0%; males 52.0%). Saunders (1978) found no significant sex difference for this trait in her study of the Eskimo-Aleut, Mobridge and Libban samples. The male preponderance in the black sample and the slight female preponderance in the white sample together with the results of Saunders (1978) indicate that sexual dimorphism is not marked in this trait.

C. Frequency of Bipartite Foramen Transversarium at Various Cervical Levels in S.A. Black and White Samples (Tables 17 and 18)

A bipartite foramen transversarium occurred most frequently at the sixth cervical vertebral level in both S.A. black (40.7%) and S.A. white males (47.8%) (Table 17) and also in S.A. black females (48.1%) and S.A. white females (47.9%) (Table 17). When the results for males and females were combined, the frequency for bipartite foramen transversarium in C6 was 43.8% in blacks and 47.9% in whites. Le Double (1912) found the trait most frequently on C6 and most often bilaterally. This finding was also reported by the study of Saunders (1978) on the Eskimo-Aleut sample. Tulsi (1975 cited in Saunders, 1978) similarly found the highest frequency of this variation to occur in C6 in a sample of Australian Aborigines.

In the black combined-sex sample a bipartite foramen transversarium occurred next most frequently at C5 (33.0%). This was followed by C7 (8.8%), C1 (8.2%), C4 (5.1%) and C3 (1.0%). No bipartite foramina transversaria were

present in C2. This order of deceasing frequency was similar in the S.A. white combined-sex sample (C6 - 47.9%, C5 - 22.3%, C7 - 14.9%, C1 - 10.6%, C4 - 3.2% and C3 - 1.1%). In view of the similar results in the black and white samples, the frequencies were combined to provide a global figure for the discussion. These combined-group frequencies were 45.1% in C6, 29.5% in C5, 10.8% in C7, 9.0% in C1, 4.5% in C4 and 1.0% in C3.

Table 17: The frequency of Bipartite Foramen Transversarium in the Various Cervical Vertebral Levels in the S.A. Black and White Samples.

BIPARTITE FORAMEN TRANSVERSARIUM								
	TOTAL BLACK				TOTAL WHITE			
	MALE	%	FEMALE	%	MALE	%	FEMALE	%
C1	8	7.1	8	9.9	5	10.9	5	10.4
C2	--	--	--	--	--	--	--	--
C3	2	1.8	--	--	--	--	1	2.1
C4	9	8.0	1	1.2	2	4.4	1	2.1
C5	38	33.6	26	32.1	10	21.7	11	22.9
C6	46	40.7	39	48.1	22	47.8	23	47.9
C7	10	8.8	7	8.7	7	15.2	7	14.6
	113		81		46		48	

Table 18: The frequency of bilateral and unilateral bipartite foramina transversaria in the S.A. black and white samples.

BIPARTITE FORAMEN TRANSVERSARIUM												
	TOTAL BLACK						TOTAL WHITE					
	B	%	UR	%	UL	%	B	%	UR	%	UL	%
C1	7	43.8	5	31.3	4	25.0	2	20.0	3	30.0	5	50.0
C2	--	--	--	--	--	--	--	--	--	--	--	--
C3	1	50.0	1	50.0	--	--	--	--	1	100.0	--	--
C4	3	30.0	3	30.0	4	40.0	--	--	2	66.7	1	33.3
C5	27	42.2	24	37.5	13	20.3	12	57.1	5	23.8	4	19.1
C6	49	57.6	20	23.6	16	18.8	29	64.4	9	20.0	7	15.6
C7	8	47.1	5	29.4	4	23.5	4	28.6	7	50.0	3	21.4
	95		58		41		47		27		20	

D. Bilaterality and Unilaterality of Bipartite Foramen Transversarium (Table 18 gives the results for the combined black and white samples.)

In the total black S.A. sample, a bilateral bipartite foramen transversarium was present in 49 (57.7%) out of a total of 85 sixth cervical vertebrae affected. The condition was unilateral in 20 vertebrae on the right side (23.6%) and in 16 vertebrae (18.8%) on the left side. In the total white S.A. sample, there was a similar trend for the sixth cervical vertebra. In this group, a bilateral bipartite foramen transversarium was present in 29 (64.4%) out of a total of 45 sixth cervical vertebrae affected. This was again followed by a unilateral right bipartite foramen (20.0%) and a unilateral left (15.6%). This trend was again repeated for C5, where the bilateral bipartite foramen transversarium was more frequent in both the total black (42.2%) and white S.A. samples (57.1%). At other cervical vertebral levels, the bilaterality and unilaterality of bipartite foramen transversarium occurred infrequently with a slight unilateral preponderance but this was not significant.

E. Discussion

The foramen transversarium from C1 to C6 transmits the vertebral artery, a plexus of vertebral veins and a sympathetic nerve plexus. The seventh cervical transverse foramen usually transmits an accessory vertebral vein which descends from the venous plexus around the vertebral artery. Rarely, it may transmit the vertebral artery (Williams *et al.*, 1989). The accessory foramen of a bipartite foramen transversarium of C6 (or any other cervical vertebra) transmits veins from the venous plexus accompanying the vertebral artery and possibly nervous elements from the sympathetic plexus. Le Double (1912) observed the accessory foramen transversarium to be present most frequently on C6 and most often bilaterally. In the present study, bilateral foramina transversaria too occurred most frequently at C6 and the bilateral expression of this trait was the most common.

Le Double (1912) examined a sample of eight human embryos but found no bipartite foramina transversaria. Saunders (1978) however, found double foramina in foetuses and newborn infants. In addition, she noted a significant decrease of the trait from the young to the old in adults. She

was not able to account for the latter finding nor for the causal factors of this variation. She suggested however, that the presence of an accessory foramen could be influenced by the growth of arterial, venous and nervous channels in the embryo and that these channels may persist in the adult. Such channels she added, could also influence the bilateral and unilateral expression of this trait. She suggested further that venous channels were the most important factors in the development of accessory foramina transversaria. The present study supports these suggestions and offers a tentative theoretical explanation for the presence of bipartite foramina transversaria at varying cervical levels.

It is noteworthy that no bipartite foramina transversaria were present in C2, three only at C3 (1.0%), 13 (4.5%) at C4 and 26 (9.0%) at C1. In contrast their presence in the lower three cervical vertebrae is much higher; that in C6 being the highest (45.1%) followed by 29.5% in C5 and 10.8% in C7. It is noteworthy that the latter two vertebrae lie on either side of C6. It is tentatively suggested that these differences in frequencies of bipartite foramina may be associated with the anatomy (formation and drainage) of the vertebral vein.

Veins from the internal vertebral plexus and from the deep muscles of the back unite to form the vertebral vein in the suboccipital triangle. The vessel then enters the foramen transversarium of the atlas in company with the vertebral artery. Both vertebral artery and vein descend to enter the foramen transversarium of C2. The vein has now formed a dense plexus around the vertebral artery and is thus in close association with it. This passage through the foramina transversaria of C1 and C2 is tightly circumscribed by bones and ligaments and it is suggested that the rigid and undeviating pathway of the vertebral artery as it inclines laterally from the foramen transversarium of C2 and then ascends vertically to the foramen transversarium of C1 thus forming a loop, imposes stable conditions on the venous plexus. Hence, the few accessory foramina reported at upper cervical levels, C3 in particular (1.0%), C4 (4.5%) and the highest number being in C1 (9.0%). This slightly higher number of bipartite foramina transversaria in C1 may be attributed to the relative instability of the venous channels ie. the tributaries, which coalesce at this level to form the vertebral vein.

The vertebral artery and its accompanying venous plexus descend through successive foramina, but now have different pathways. The vertebral artery has arisen from the subclavian artery and ascends to enter the foramen transversarium of C6. The venous channels coalesce at C6 to form, once again, the vertebral vein. This vein emerges from the foramen transversarium of C6 and runs downwards to open into the brachiocephalic vein. It is postulated that the dynamic flow towards the large brachiocephalic vein at these lower cervical levels may account for the persistence of accessory venous channels and that these channels are present in the adult in the form of accessory bipartite foramina transversaria. This theory is based on Saunders' (1978) findings that double foramina are present in foetuses and newborn infants and also on her suggestion that venous channels are the most important factors in the development of accessory foramina. It is surmised that more than one venous pathway exists between C6 and the brachiocephalic vein in developing foetuses and that the dynamic flow towards the vein (at this level) accounts for the persistence of more than one channel in the adult. It is postulated that the influence of the dynamic flow may extend to the adjacent developing C5, though to a lesser degree.

In summary, this suggested explanation could account for the significantly higher frequencies of bipartite foramina in C6 (45.1%) and, to a lesser extent in C5 (29.5%) than in vertebrae at higher levels.

This postulated explanation relating to dynamic flow may also be linked to variations in levels of occurrence of bilateral bipartite foramina. Since the flow is symmetrical, that is present on both sides, it may account, at least in part for the greater number of vertebrae with bilateral bipartite foramina at C6 and possibly also at C5 than at the higher levels

F. Summary and Conclusions

The Sotho (49.0%) and C.Nguni (40.0%) samples presented with a significantly higher frequency than the N.Nguni (27.0%) for bipartite foramina transversaria. The combined S.A. black sample had a significantly lower frequency (31.3%) for the trait than whites (56.0%). No comparable studies on other population groups with which to compare these results were found in the literature available to me.

Bipartite foramina transversaria were present more often in S.A. black males (44.0%) than females (18.7%). This male preponderance was present too in the tribal subgroups but was not significant. In contrast, there was a slight female preponderance in S.A. whites but this was not significant.

Bipartite foramina transversaria were present most frequently in C6 (43.8%) in both the S.A. black and white combined-sex samples (47.9%). This finding confirms reports in the literature by Le Double (1912), Tulsi (1975 cited in Saunders, 1978) and Saunders (1978). Relatively high frequencies were present too, in the both groups at the level of C5 (black 33.0%, white 22.3%) and C7 (black 5.2%, white 14.9%). The only vertebra where a bipartite foramen transversarium was not present was the axis and the condition was rare too, in the adjacent C3 (blacks 1.0%, whites 1.1%).

At C6, bilateral bipartite foramina transversaria were present more often than the unilateral condition. This tendency was present in both black and white samples.

Venous channels are suggested by Saunders (1978) as being the most important factors in the development of accessory foramina transversaria. On the basis of these findings a theory is postulated to account for the relatively high frequency of bilateral foramina transversaria at lower cervical levels (C6 in particular) as compared with the low numbers at upper cervical levels.

CHAPTER 10

BIPARTITE SUPERIOR ARTICULAR FACETS OF THE ATLAS

A. Bipartite Superior Articular Facets of the Atlas in the S.A. Black and White Samples (Table 19, Figures 16 and 17)

In the black S.A. sample, the N.Nguni (21.0%) presented with the highest frequency of bipartite superior articular facets of the atlas. This was followed by the C.Nguni (16.0%) and the Sotho (12.0%) (Table 19, Figure 16). No statistically significant intertribal differences were noted. The tribal subgroups were thus combined. A bipartite superior articular facet of the atlas was found in 16.3% of the black sample and 25.0% of the white sample (Table 19, Figure 17). There was no statistically significant difference between these two groups.

Table 19: The Frequency of Bipartite Superior Articular Facets of the Atlas in the Black and White S.A. Samples

SAMPLE	PERCENTAGE FREQUENCY		
	MALE	FEMALE	MALE + FEMALE
Sotho	10.0	14.0	12.0
C.Nguni	20.0	12.0	16.0
N.Nguni	32.0	10.0	21.0
TOTAL S.A. BLACK	20.7	12.0	16.3
TOTAL S.A. WHITE	28.0	22.0	25.0

B. Bipartite Superior Articular Facets of the Atlas in Other Human Populations

Lanier (1939) reported a frequency of 20.0% for black American males and 13.0% for white American males for bipartite superior articular facets. The S.A. black male sample (20.7%) presents a frequency similar to that for the American black male sample (20.0%). The S.A. white male sample however, has a higher frequency (28.0%) than that of the white American male sample (13.0%). A lower frequency was found by Singh (1965) for Asiatic atlases (5.5%). The frequency thus varies from 5.5% to 28.0% in different population groups.

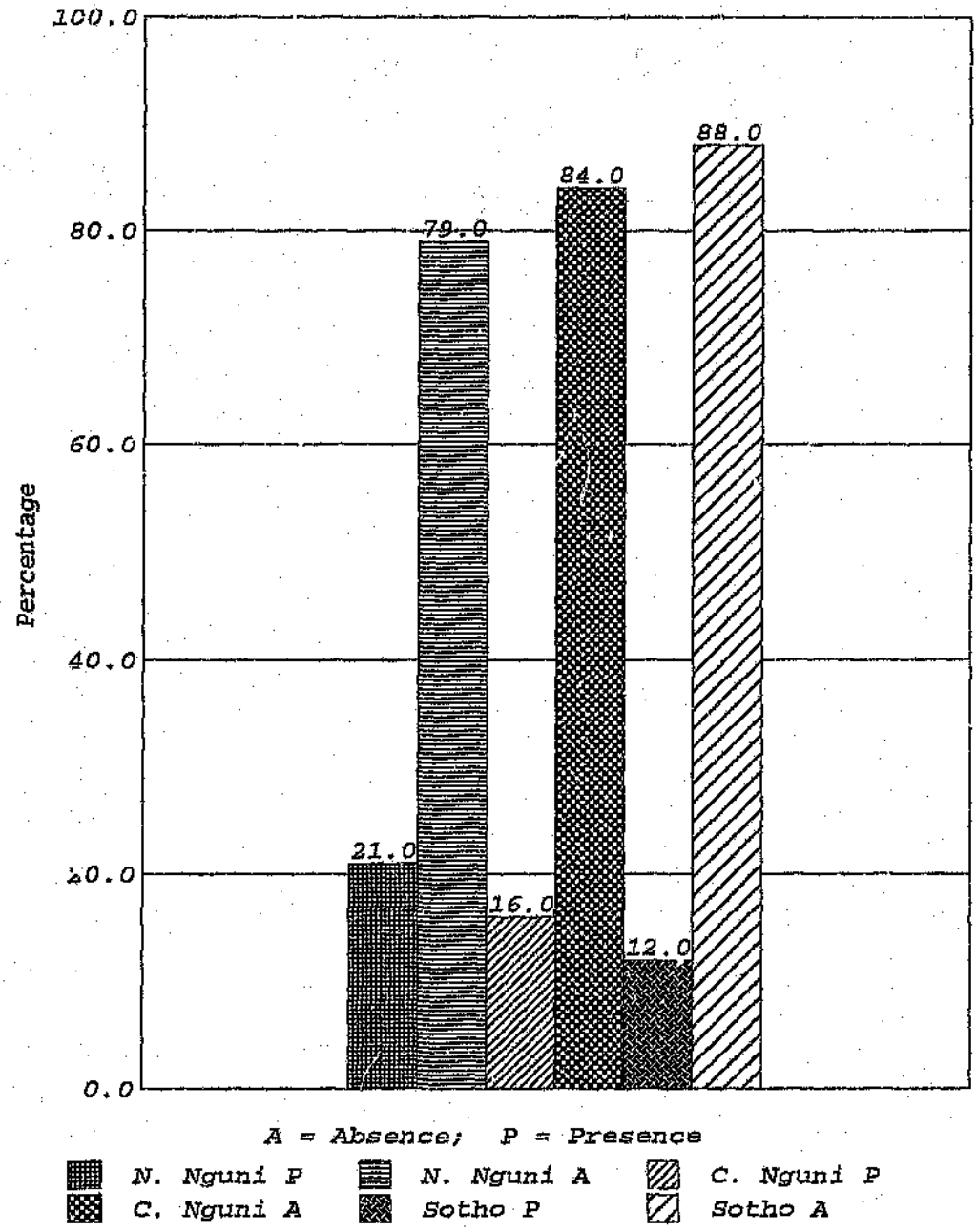

Fig. 16 Incidence of bipartite superior articular facets of the atlas in the N. Nguni, C. Nguni and Sotho tribal subgroups (males plus females combined).

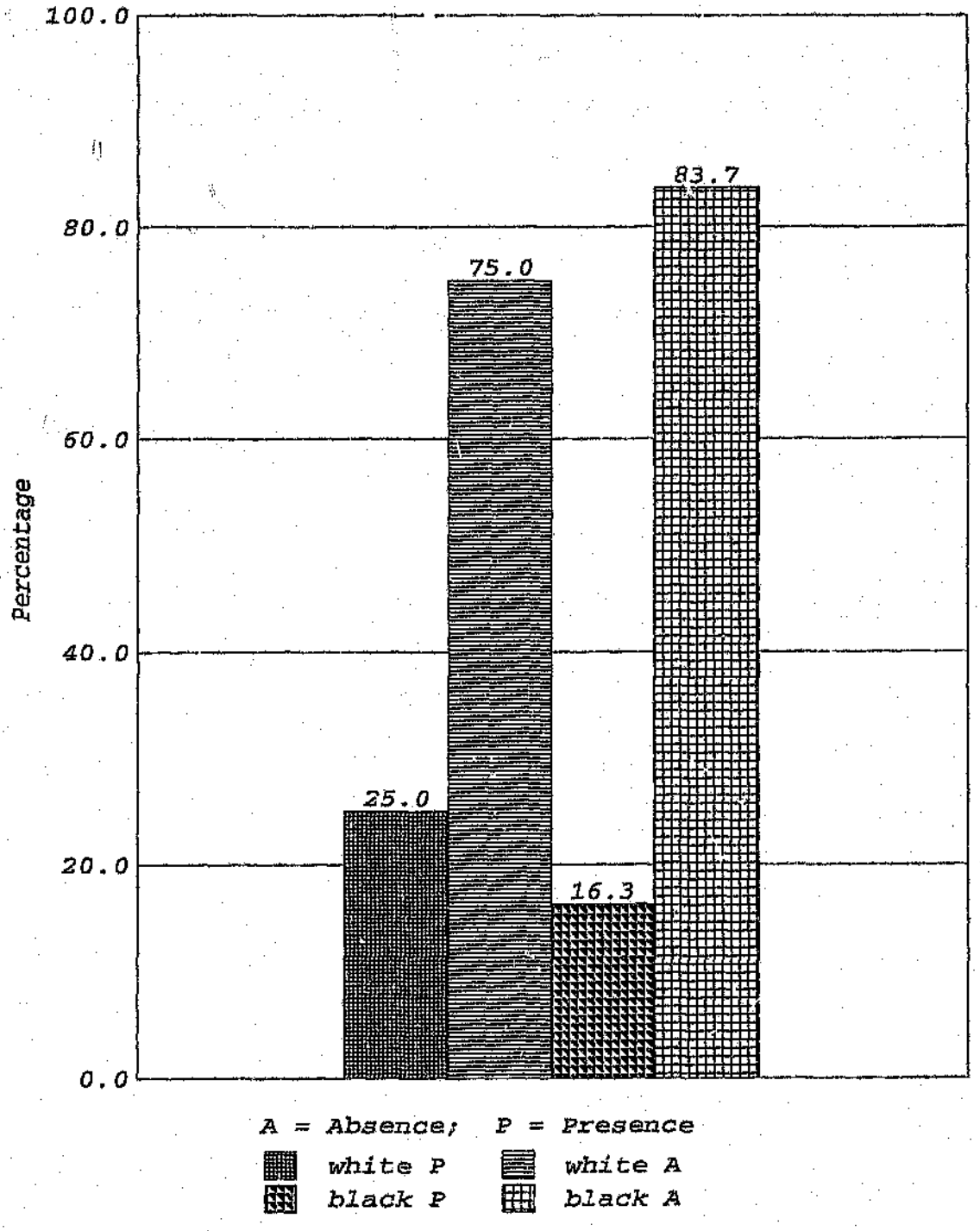

Fig. 17 The incidence of bipartite superior articular facets of the atlas in the total black and white S.A. samples.

C. Sex Differences (Table 19)

The N.Nguni male sample had a significantly ($P<0.05$) higher frequency of bipartite superior articular facets of the atlas (32.0%) than females (10.0%). The C.Nguni male sample too, presented with a higher frequency (20.0%) than the C.Nguni female sample (12.0%), but this was not statistically significant. In contrast, the Sotho sample, had a higher frequency for the females (14.0%) than for males (10.0%). This difference was not statistically significant. The tribal subgroups were combined and in both the S.A. black and white samples, the males (20.7%; 28.0% respectively) showed a higher frequency of this trait when compared to females (12.0%; 22.0% respectively). These differences were not, however statistically significant. Finnigan (1978), in his study of the Eskimo, also found the male sample to have a higher frequency of bipartite superior articular facets than the female sample. Thus males in general, tend to have a higher frequency of bipartite superior articular facets of the atlas than females.

D. Bilaterality and Unilaterality of Bipartite Superior Articular Facets of the Atlas

A bilateral bipartite superior articular facet of the atlas was present in 17 (34.6%) skeletons in the black S.A. sample and in 13 (52.0%) of the white S.A. sample (Table 20). A unilateral right bipartite superior articular facet was present in 16 (32.7%) skeletons in the black sample and in four (16.0%) of the white sample. A unilateral left bipartite superior articular facet was present in 16 (32.7%) of black skeletons and a unilateral right bipartite superior articular facet in 8 (32.0%) white skeletons. Thus, the bilateral expression of this trait was the most frequent, although its occurrence was not significantly different from the unilateral condition. Lanier's (1939) study also found, as in the S.A. samples that the bilateral expression of this trait was the most common. He reported that black American males presented a 50.0% frequency of bilateral bipartite superior articular facets and white American males a 46.0% frequency. In contrast, Singh (1965) found the bipartite unilateral left facet (52.6%) to be the most frequent, followed by the unilateral right (31.6%), whereas the bilateral bipartite superior articular facet occurred in only 15.8% of skeletons. It would seem

Table 20: The Bilateral, Unilateral Right or Left Occurrence of Bipartite Superior Articular Facets of the Atlas in the Black and White S.A. Samples

	BIPARTITE SUPERIOR ARTICULAR FACETS OF THE ATLAS											
	BILATERAL				UNILATERAL RIGHT				UNILATERAL LEFT			
	MALE	FEMALE	TOTAL		MALE	FEMALE	TOTAL		MALE	FEMALE	TOTAL	
	n	n	n	%	n	n	n	%	n	n	n	%
Sotho	3	–	3		1	2	3		4	2	6	
C.Nguni	2	2	4		5	–	5		3	4	7	
N. Nguni	9	1	4		4	4	8		3	–	3	
TOTAL BLACK	14	3	17	34.6	10	6	16	32.7	10	6	16	32.7
S.A. WHITE	6	7	13	52.0	2	2	4	16.0	6	2	8	32.0

that there is no discernable pattern for bilaterality and unilaterality and it cannot be related to any one population group.

E. Discussion

Singh (1965) reported that the superior articular facets of the atlas may take a variety of forms. The facet may be long, more or less oval, and concave. Alternatively, it may consist of two distinct facets which are separated either by a groove or a ridge of bone. The latter description was adopted for the definition of a bipartite superior articular facet in this survey.

Singh (1965) examined variation in the superior articular facets in a random sample of 200 dry bones in Asiatics. He was impressed with the wide range of shape and form. He reported that 86.0% of all atlas vertebrae demonstrate some form of a tendency towards facet separation, i.e. they had bipartite articular facets. von Torklus and Gehle (1972) suggested that the occurrence of bipartite atlas condylar facets was owing to the fact that the anterior arch of the atlas, together with the anterior part of the superior articular facet originates from the pro-atlas, whilst the posterior arch together with the posterior part of the superior articular facet develop independently. Singh (1965) alternatively suggested that the occipital and vertebral components of the atlanto-occipital joint have both been undergoing a continuous succession of changes. He suggested that the atlanto-occipital joint developed as a result of the mode of life of the animal. According to him, the atlanto-occipital joint developed from a primitive triple condyle on the occipital bone which comprised a ventral median condyle nearly circular in shape and two elongated lateral condyles situated dorsally on each side. In amphibians the lateral condyles have become dominant, while in birds, the median condyle has gradually increased along with recession and ultimate exclusion of the lateral condyles. In mammals reverse changes have taken place where only the lateral condyles remain which restricts the movements of the head to nodding only. Singh (1965) concluded that the tendency of the superior articular facets of the atlas to split into two separate facets was an evolutionary trend resulting from restrictions of movements of the atlanto-occipital joint. Since this study did not investigate development of the

atlas or movement at the atlanto-occipital joint, no conclusions relating to these theories are possible. The theory of Singh (1965) however, is favoured.

F. Summary and Conclusions

In the S.A. white sample there was a tendency for a higher frequency of bipartite superior articular facets of the atlas (25.0%) than in the black group (16.3%) but the difference was not significant. Both S.A. black and white males tend to exhibit this variation more frequently than females, though these differences were not significant. The bilateral expression of this trait was the more frequent in both the black and white groups (34.6% and 52.0% respectively) but this was not significantly different from the unilateral expression of the [illegible]t. Singh's (1965) theory that bipartite superior articular facets may be the expression of an evolutionary trend is favoured.

CHAPTER 11

COMPLETE POSTERIOR BRIDGE OF THE ATLAS

A. Posterior Bridge of the Atlas in the S.A. Black and White Samples

(Table 21, Figures 18 and 19)

A posterior bridge of the atlas was present in 19.0% of the N.Nguni sample. This was followed by somewhat lower frequencies for the C.Nguni (15.0%) and the Sotho (10.0%) (Table 21 and Figure 18). There were no statistically significant intertribal differences and the subgroups were combined to form the S.A. black sample. This showed a higher frequency of posterior bridge of the atlas (14.7%) than the white sample (10.0%) (Table 21 and Figure 19). This difference was not however, statistically significant.

Table 21: The Frequency of a Complete Posterior Bridge of the Atlas in the Black and White S.A. Samples

SAMPLE	PERCENTAGE FREQUENCY		
	MALE	FEMALE	MALE + FEMALE
Sotho	10.0	10.0	10.0
C.Nguni	20.0	10.0	15.0
N.Nguni	22.0	16.0	19.0
TOTAL SA BLACK	17.3	12.0	14.7
TOTAL SA WHITE	10.0	10.0	10.0

B. Posterior Bridge of the Atlas in Other Human Populations

Ossenfort (1926) found a complete posterior bridge of the atlas in 12.0% of 102 American white and 12.0% of 81 American black skeletons. This is comparable to the findings in the present study (S.A. blacks 14.7% and S.A. whites 10.0%). A study by Selby *et al.* (1955) on American whites reported a frequency of 12.1%. Another study on American whites by Saunders *et al.* (1978) reported a frequency of 9.3%. The frequencies obtained in these two studies (12.1% and 9.3%) are similar to the results for the S.A. white sample (10.0%). Thus, the frequency for the presence of a complete posterior bridge on the atlas varies little in different population groups and ranges from 9.3% in American whites to 14.7% in S.A. blacks.

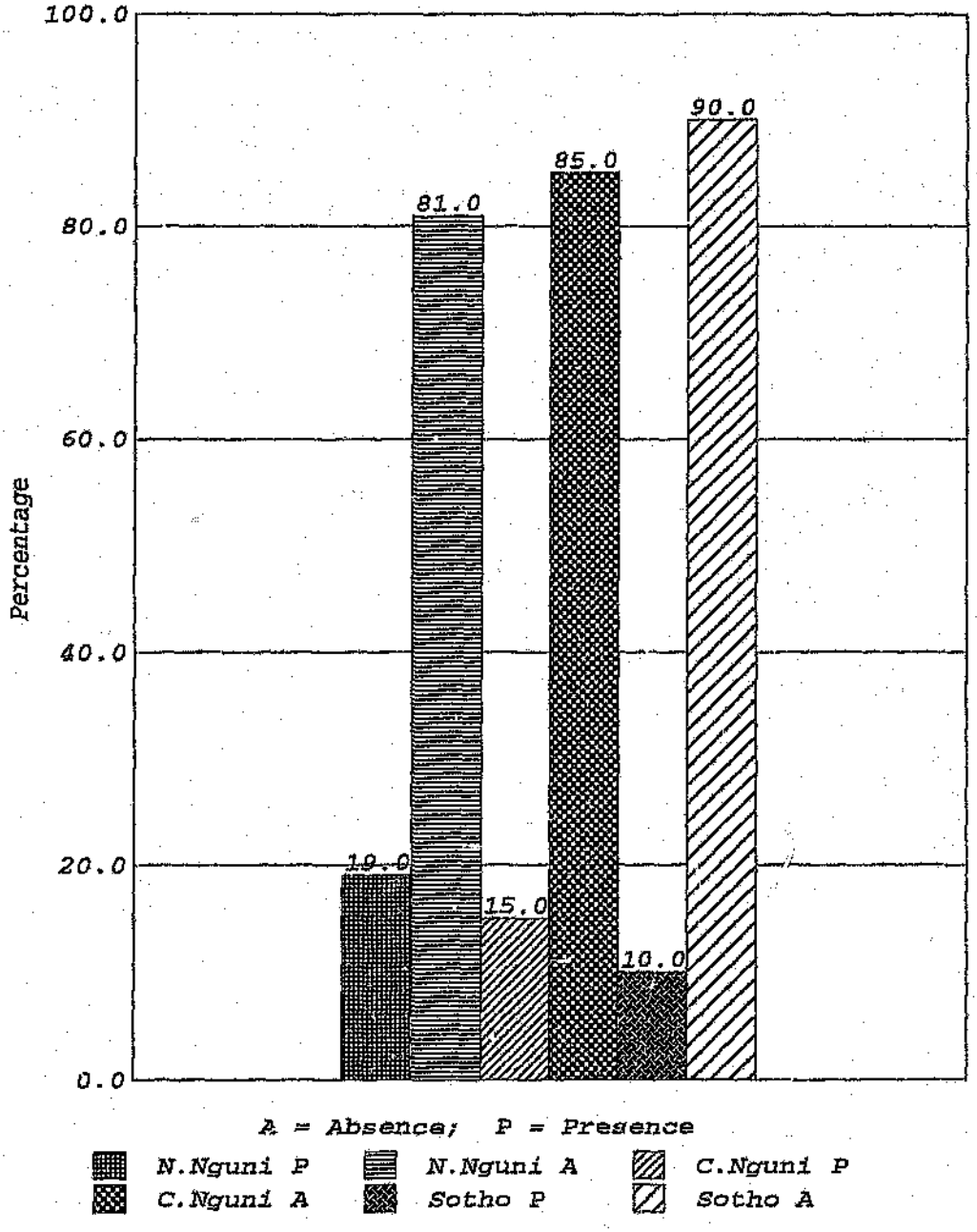

Fig. 18 The incidence of a complete posterior bridge of the atlas in the N.Nguni, C.Nguni and Sotho tribal subgroups (males plus females combined).

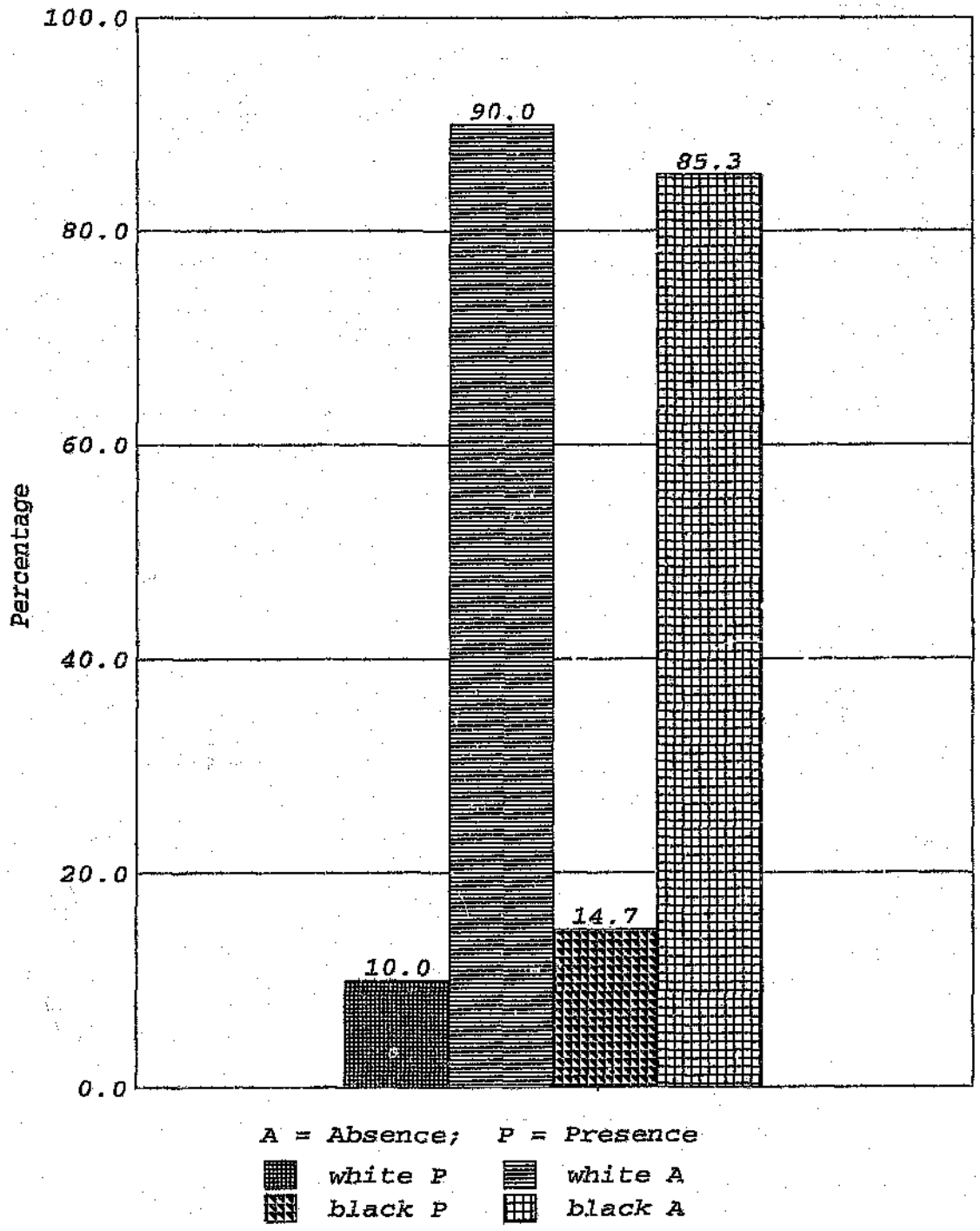

Fig. 19 The incidence of a complete posterior bridge of the atlas in the total black and white S.A. samples.

C. Sex Differences

A complete posterior bridge of the atlas was present more often in black S.A. males (17.3%) than in females (12.0%). The difference however, was not statistically significant (Table 21). White S.A. males and females however, presented with equal frequencies (10.0%). A male preponderance was reported in the studies by Selby et al. (1955) and Saunders et al. (1978) on two American white samples. Thus in general, there would appear to be a male preponderance for this trait.

The Bilaterality or Unilaterality of Posterior Bridging of the Atlas

A complete posterior bridge of the atlas was present in 54 (13.5%) of a total of 400 atlases (S.A. black plus white atlases combined). Of the 54 atlases, 24 (44.4%) presented the bilateral condition, 13 (24.1%) the unilateral right condition and 17 (31.5%) the unilateral left condition (Table 22). Significantly more males ($P<0.05$) presented with the unilateral right trait than females.

Table 22: The Bilateral, Unilateral Right and Unilateral Left Occurrence of a Complete Posterior Bridge of the Atlas in Black and White S.A. Samples

	POSTERIOR BRIDGE OF ATLAS								
	BILATERAL			UNILATERAL RIGHT			UNILATERAL LEFT		
	MALE	FE-MALE	TOTAL	MALE	FE-MALE	TOTAL	MALE	FE-MALE	TOTAL
Sotho	3	3	6	1	-	1	1	2	3
C.Nguni	2	2	4	5	-	5	3	3	6
N.Nguni	6	4	10	3	2	4	2	3	5
TOTAL BLACK n = 300	11	9	20	9	1	10	6	8	14
TOTAL S.A. WHITE n = 100	2	2	4	2	1	3	1	2	3
TOTAL BLACK AND WHITE n = 400	13	11	24	11	2	13	7	10	17

E. Discussion

The posterior bridge of the atlas spans the groove for the vertebral artery and extends from the lateral mass of the atlas to the posterior arch. It thus creates a bony foramen through which the vertebral artery and first cervical spinal nerve pass. It has been described as the retro-transverse foramen (Le Double, 1912; Romanus and Tovi, 1964), ponticulus posticus (Selby *et al.*, 1955) and foramen retro-articulare superiores (Von Torklus and Gehle, 1972).

Three theories have been proposed for its formation. Very early workers proposed the bridge to be a direct homologue of the superior articular process of other mammals (Cleland, 1861; Allen, 1879; McAlister 1893). Others have suggested that the bridge is a remnant of an occipital vertebra and is derived from the embryonic tissue of the dorsal arch of the pro-atlas (1927 Von Hayek cited in Saunders, 1978).

Alternatively, Barge (1918) and . .lwig (1953), believed that the atlas bridge is simply a late ossification of the posterior atlanto-occipital membrane. During my observations, I noticed that the bridge is occasionally incomplete. Since the complete and incomplete bridge corresponds to the free border of the posterior atlanto-occipital membrane as it arches over the vertebral artery, Barge's (1918) and Ludwig's (1953) explanation would seem to account for both an incomplete and a complete bridge. This study thus supports the suggestion that the posterior bridge of the atlas may be due to ossification of the free edge of the posterior atlanto-occipital membrane and is thus a hyperostotic bon. trait. Ossenfort (1926) and Corruccini (1974) have suggested that hyperostotic or excess bone traits are more common in males. Thus the male preponderance found in S.A. blacks as well as that found in American whites by Selby *et al* (1955) and Saunders *et al* (1978) all offer support for this suggestion.

Selby *et al.* (1955) found that siblings and parents of affected children show a higher proportion of atlas bridging than in the general population, whilst the converse was true of the parents of unaffected children. When one parent was affected about half of the children showed atlas bridging. With both parents affected, the proportion of affected children was almost 100%. Selby *et al.* (1955) by their statistical analyses and examination of pedigrees

suggested that this trait was familial, genetic and though influenced by sex, probably inherited as a Mendelian dominant trait.

F. Summary and Conclusions

Complete posterior bridge of the atlas was present more frequently in the S.A. black sample (14.7%) than the white sample (10.0%) but this difference was not significant. The frequencies reported for various populations are similar and vary from 9.3% to 12.1%. The trait has been shown to have a genetic basis and it is probable that it is inherited as a Mendelian dominant trait (Selby *et al*, 1955).

Black males present a higher frequency of this variation than black females, but this finding was not significant. The bilateral expression of this trait (44.4%) was more common than either the unilateral left [illegible] or right (24.1%) condition but this finding was not significant. The finding of both incomplete as well as complete bridges of the atlas in the present study offers support for a suggested explanation that the formation of the bridge is owing to ossification of the atlanto-occipital membrane and it is thus a hyperostotic bone trait.

CHAPTER 12

OSSIFICATION OF THE APICAL LIGAMENT OF THE DENS OF THE AXIS

A. Ossification of the Apical Ligament of the Dens of the Axis in S.A. Black and White Samples (Table 23, Figures 20 and 21)

Ossification of the apical ligament was present in 12.0% of the Sotho tribal subgroup and in 10.0% of both the C.Nguni and N.Nguni subgroups (Table 23, Figure 20). The differences among these groups were not statistically significant. The frequency for ossification of the apical ligament was 10.7% in the combined S.A. black sample and 18.0% in the white sample (Table 23, Figure 21). Although the white sample showed a higher frequency of this variation, the difference was not statistically significant.

Table 23: The Frequency of Ossification of the Apical Ligament of the Axis in the Black and White S.A. Samples

SAMPLE	PERCENTAGE FREQUENCY		
	MALE	FEMALE	MALE + FEMALE
Sotho	16.0	8.0	12.0
C.Nguni	12.0	8.0	10.0
N.Nguni	18.0	2.0	10.0
TOTAL SA BLACK	15.3	6.0	10.7
TOTAL SA WHITE	20.0	16.0	18.0

B. Frequency of Ossification of the Apical Ligament of the Axis in Various Populations

Frequencies for the ossification of the apical ligament of other living black and white population groups were not found in the literature. However, results were available for three archaeological skeletal samples studied by Saunders (1978). These were the Eskimo-Aleut, the Arikara Indian and the Great Lakes Late Woodland Indian sample. The frequencies were 12.9%, 14.2% and 16.9% respectively. Anderson (1963 cited by Saunders, 1978) found a somewhat higher frequency for ossification of the apical ligament of the axis (27.0%) in Indians from the Fairty Ossuary archaeological site. Comparison of these results with those of the present study shows that the S.A. black

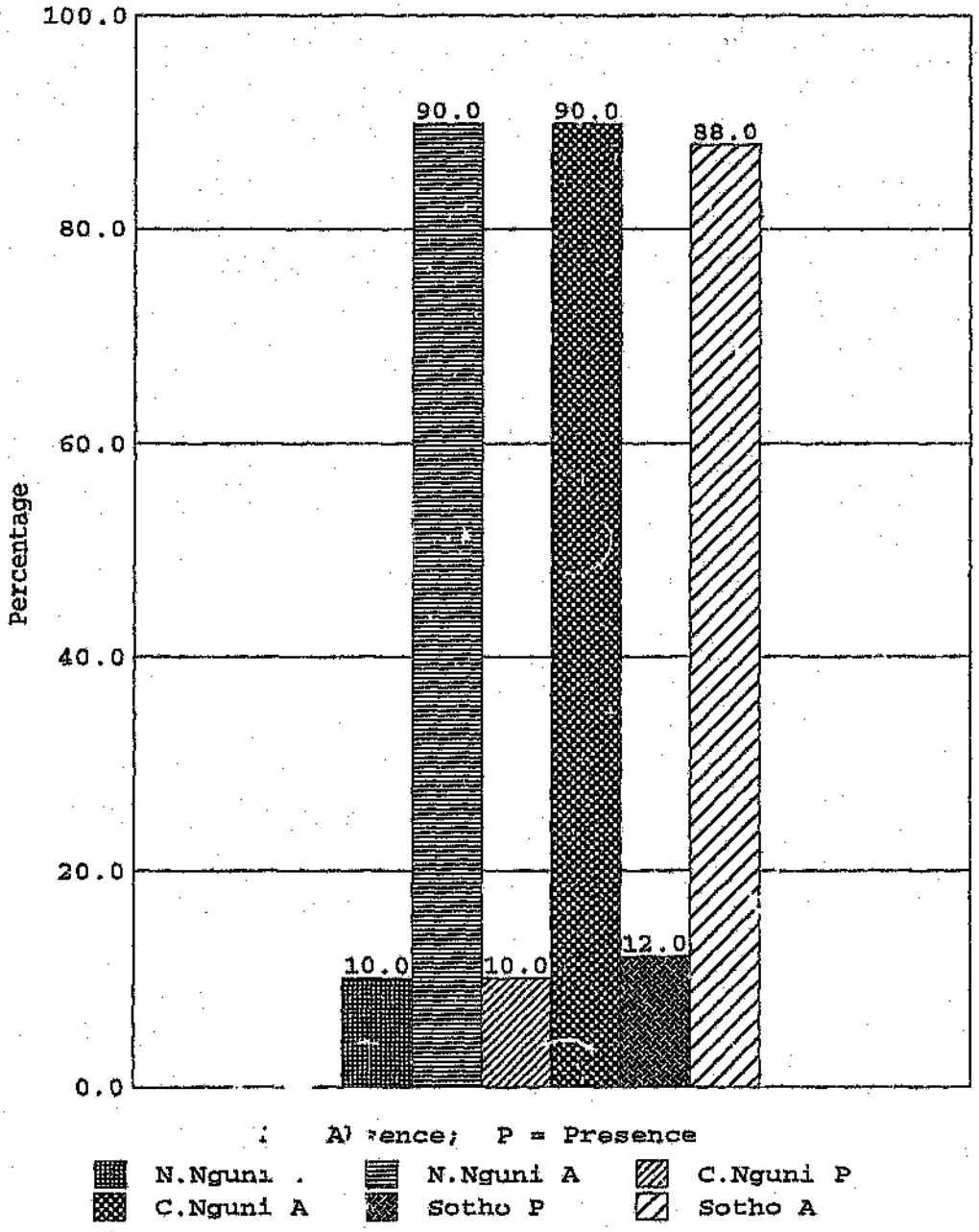

Fig. 20 The incidence of ossification of the apical ligaments of the dens of the axis in the N.Nguni, C.Nguni and Sotho tribal subgroups (males plus females combined .

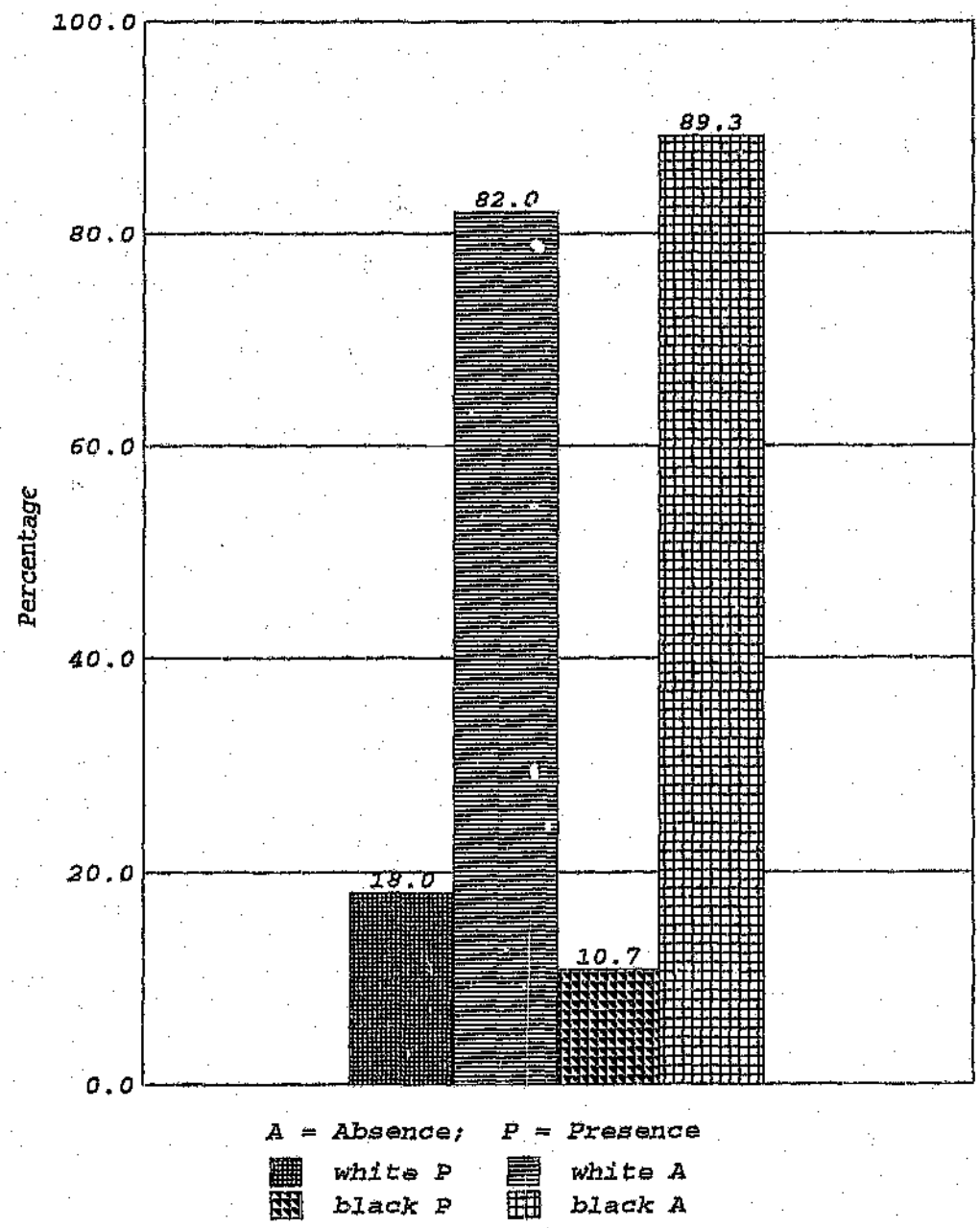

Fig. 21 The incidence of ossification of the apical ligament of the dens of the axis in the total black and white S.A. samples.

sample has the lowest frequency for the trait (10.7%), whilst the S.A. white sample had the second highest of 18.0%. The highest frequency (27.0%) was from an archaeological site. The frequency of this trait is thus comparable with all but one sample from archaeological sites.

C. Sex Differences

All males in the tribal subgroups had higher frequencies for ossified apical ligaments than females. The only significant difference however was for the N.Nguni sample where males (18.0%) had a significantly ($P<0.05$) higher frequency of ossified apical ligaments than females (2.0%). The tribal subgroups were combined to form the S.A. black sample. In both the S.A. black (males - 15.3%, females - 6.0%) and white samples (males - 20.0%, females - 16.0%), males had a higher frequency of the trait. These differences were not however, statistically significant. Saunders (1978) too found a slightly higher frequency of ossified apical ligaments for males in her archaeological studies, though this was not significant. This male preponderance in all samples offers support for the suggestions of Ossenfort (1926) and Corruccini (1974) that hyperostotic bone traits are more common in males.

D. Discussion

Williams *et al.* (1989), regards the apical ligament as a rudimentary intervertebral disc, probably containing traces of notochord. von Torklus and Gehle (1972) state that the ossification of the dens (which is the embryological body of the atlas) starts at the base of the axis and proceeds cranially in two rays. The two centres appear at about the fifth month of intra-uterine life and fuse at birth. They note that an occasional inconstant ossification centre, the ossiculum terminale Bergmann, makes an appearance at the tip of the dens between the ages of 10 months and 2 years. This ossiculum is said to be derived from the centre of the pro-atlas. Normal ossification is complete by the tenth to twelfth year. The ossiculum was found in 26% of 70 children between the ages of 5 and 11 years (Cattel and Filtzer, 1965). von Torklus and Gehle (1972) state that the ossiculum lies at the level of the tips of the two ossification rays of the dens. These two ossification rays overgrow the ossiculum and incorporate it between them. This prompted von

Torklus and Gehle (1972) to speculate that when ossification of the apical ligament is present, the two ossification rays of the dens do not overgrow the ossiculum. Instead, the ossiculum projects above the dens to form the fused apical ligament.

The evidence that an occasional ossification centre results in the presence of an ossiculum in some 26% of a sample of developing children prompts this study to favour the theory of von Torklus and Gehle (1972).

E. Summary and Conclusions

No significant intertribal differences were present among the frequencies for ossification of the apical ligament. Ossification of the apical l[illegible] was somewhat higher in S.A. whites (18.0%) than in S.A. blacks (10[illegible]) but this too was not significant.

Sex differences were noted in the form of a male preponderance in both black and white S.A. samples, as well as in all Saunders' (1978) samples from archaeological sites.

The theory of von Torklus and Gehle (1972) that the excess bone trait of an ossified apical ligament may be derived from an ossiculum is thought to be more likely than it being a rudimentary intervertebral disc.

CHAPTER 13

SUMMARY AND GENERAL CONCLUSION

Since people vary in many bodily characteristics, both structural and functional, the presence of morphological differences among various population groups is well documented. Practically all human populations for which adequate records are available, exhibit some form of morphological variability, whether of bone or soft tissue. Variability is characteristic of all forms of life. For example, children of the same family may only bear slight resemblances to one another to the extent that monozygotic twins may even differ from each other. The study of the variability of man encompasses the study of human races. The present dissertation examines the cervical region of the vertebral column for evidence of variability of certain traits and their variability in black and white S.A. population groups.

The S.A. black group consisted of samples from three tribal subgroups, the N.Nguni, the C.Nguni and the Sotho. Since no significant intertribal differences were found (save for the frequency of cervical rib and bipartite foramen transversarium) the subgroups were pooled to form a sample representative of S.A. blacks.

1. Numerical Variation of Cervical Vertebrae

A reduction in number of cervical vertebrae is rare in man. This was confirmed in the present study on S.A. blacks where only one column had six cervical vertebrae (0.3%). This column belonged to a C.Nguni male. No white columns showed a reduction in the number of cervical vertebrae. It was thus not possible to demonstrate any intergroup differences but variation in vertebral numbers for the total presacral column has however been shown by some workers to indicate genetic differences among population groups. It is thus suggested that since numerical variation of cervical vertebrae occurs so infrequently, their numbers should be examined in conjunction with the total presacral column.

2. Occipitalization of the Atlas

Occipitalisation of the atlas was not present in either black or white S.A. samples. Some workers have suggested that occipitalisation be regarded as a reduction in the number of cervical vertebrae. The majority of workers

however consider the trait to be due to developmental factors. They thus count an occipitalised atlas as C1. The present study subscribes to the latter view.

3. Cervical Rib

The vertebral variant of cervical rib on C7 was present significantly more frequently in the N.Nguni (9.0%) and Sotho (7.0%) subgroups than in the C.Nguni (2.0%). The frequency for the combined S.A. black sample was 6.0% and this was significantly higher than that for S.A. whites (1.0%). Furthermore, the frequency for S.A. blacks was higher than that for other black, white and Asian groups reported in the literature. It is noteworthy that a skeletal study on S.A. blacks by Shore (1930) gave the second highest frequency (2.5%) among the groups. It is suggested that the high frequency may be characteristic of S.A. blacks and may have a genetic basis. These results would support a possible population difference between S.A. blacks and whites.

Bilateral cervical ribs were present more frequently (72.2%) than unilateral ribs (27.8%) in S.A. blacks. This proportion was present not only in the present (skeletal) sample but also in a radiographic study on S.A. blacks by Asvat and Fell (1990) where bilateral cervical ribs were present in 72.7% of radiographs with cervical ribs. These results are in agreement with the studies of Keen (1907) and Tilmann (1908 cited in Honeij, 1920) who both reported the bilateral condition in approximately two-thirds of individuals with cervical ribs.

Cervical ribs were present significantly more frequently in S.A. black males (9.3%) than in females (2.6%) There was only one skeleton with cervical rib in the small white sample and it was male. The results for S.A. blacks give a male preponderance of 77.8% in the 18 skeletons with cervical rib. There was a similar preponderance in S.A. blacks in a radiographic study of Asvat and Fell (1990). In contrast, studies on American whites (Lanier, 1939) and on a European group which consisted of 200 skeletons with cervical rib (Honeij, 1920) all show a female preponderance of cervical rib (ranging from 70.8% in the large European group to 100% in the American study). It is possible that these findings of a male preponderance of cervical rib in S.A. blacks as compared with a female preponderance in white groups, may be a characteristic of the S.A. black group.

4. Spina Bifida Occulta

The bony defect of spina bifida occulta in all cervical vertebrae (the atlas inclusive) was present in relatively high frequencies in both white (5.0%) and black (4.3%) S.A. samples. This relatively high frequency is due mainly to the numbers of vertebrae with the defect in the atlas only (whites 4.0%, blacks 3.0%). These frequencies were appreciably higher than those for spina bifida occulta in the cervico-thoracic region.

The occurrence of spina bifida occulta in the cervico-thoracic region only (with exclusion of the atlas) was analysed separately in order to compare with similar reports in the literature. The frequencies were appreciably lower than those for the atlas and were 1.7% in black and 1.0% in white South Africans. Comparable studies in the literature reveal that blacks in general tend to have higher frequencies of cervico-thoracic spina bifida occulta than whites. The frequencies for skeletal studies in blacks range from 1.7% and 3.6% in S.A. blacks, and 2.2% in West African Negroes and 2.9% in East African Negroes. The frequencies were lower in whites and range from 0.02% and 0.16% in two large radiographic studies, to 1.0% in the present skeletal study.

The incidence of spina bifida aperta has been observed to vary among different races (Leck, 1974) and a genetic basis for this trait has been suggested and is supported by the results of familial studies by workers. It is suggested that, in the light of higher frequencies of spina bifida occulta in blacks than in whites, the etiological factors thought to be responsible for spina bifida aperta may be extrapolated for spina bifida occulta. It is thus suggested that genetic factors may play a part in the expression of the lesser bony defect of spina bifida occulta in S.A. blacks and whites.

Attention is drawn to several factors which might contribute to variability in the atlas and, thus possibly to a relatively high frequency of spina bifida occulta in this bone. These include the obvious absence of a spinous process and thus the absence of its supportive and stabilizing influence in the region of the posterior arch. Linked to this is a variable pattern of ossification of the posterior arch of the atlas. A further factor might be the proximity of occipital somites to the atlas. Evidence of their influence at this junctional area is seen in spines with occipitalization of the atlas. Gladstone and Erichsen-Powell (1915) suggested that the tissue

binding the atlas to the skull at the atlanto-occipital joint does not break down to form the joint. It is noteworthy that this part of the occipital bone is developed from occipital somites: this junction between skull and vertebral column is thus a region of comparative instability, greater perhaps than the junction between the vertebrae of different regions, such as the cervico-thoracic region.

5. **Cervical Spinous Processes**

The cervical spinous processes in S.A. whites were more bifid (58.9%) than non-bifid (41.1%). Non-bifidity was however more frequent in the S.A. black sample (68.4%) and this difference between the black and white groups was significant.

The axis was consistently bifid in both groups (whites 89.0%, blacks 83.7%) and non-bifidity was the rule in the seventh cervical vertebra (blacks 99.6%, whites 98.0%). The relatively high frequency of bifidity in C2-C6 in the white group agrees in general, with statements in the literature. The high frequency of non-bifidity in C3-C7 of the S.A. black group which was also reported by Shore (1931), may be characteristic of S.A. blacks and may signify a population difference. The results of a developmental study which shows a progression from bifidity (in foetal stage) to non-bifidity in puberty and in adult life by von Eggeling (1922 cited by Shore, 1931) are tentatively suggested as a possible explanation for the findings of a preponderance of non-bifidity in black groups.

The bifurcate type of bifid spinous process predominates in the S.A. white sample, C2-C7 inclusive whereas the cleft type is characteristic of C3-C6 in the black sample.

In both the black and white S.A. groups, the clavate subtype of non-bifid spinous process was the most common and the acinate subtype the least common. The seventh cervical spinous processes were always of the clavate subtype.

6. **Bipartite Foramen Transversarium**

Bipartite foramina transversaria were present in 31.3% of S.A. blacks and 56.0% of S.A. whites and this lower frequency in blacks was significant. When present, the trait was most commonly found at C6 (blacks 43.8%, whites 47.9%) and this finding confirms a fact widely reported in the literature. Fewer bipartite foramina were present at C5 (blacks 33.0%, whites 22.3%) and the

frequency fell sharply from 5.1% (blacks) and 3.2% (whites) in C4 to the lowest frequencies of 1.0% (blacks) and 1.1% (whites) in C3. No bipartite foramina were present at C2, a finding attributed to the rigid and undeviating pathway of the vessel at this level. This influence may extend to C3 where only three vertebrae out of a total of 288 had bipartite foramina transversaria.

An explanation was sought for the relatively high frequencies of bipartite foramina transversaria in C6. Saunders (1978) postulated that venous channels were the most important factors in the development and persistence of accessory foramina transversaria. The venous plexus surrounding the vertebral artery unites at C6 to form the vertebral vein which drains into the brachiocephalic vein. It is suggested that the dynamic flow towards the large brachiocephalic vein may result in the persistence of some channels of the venous plexus at this level. Such channels would join the vertebral vein below the foramen transversarium of C6 and leave evidence of their passage in the form of accessory (or bipartite) foramina transversaria. This may account for the high frequencies of this trait at C6. The influence of dynamic flow may be felt too, at the immediately adjacent C5 where there are still an appreciable number of bipartite foramina transversaria.

Bilateral bipartite foramina transversaria were present more often than the unilateral right or left condition in C6. Bilateral foramina were present less frequently in C5 and infrequently at higher levels. It is postulated that the symmetrical nature of the dynamic flow towards the brachiocephalic vein may account for the relatively high frequency of the bilateral occurrence of this trait at C6.

Black S.A. males (44.0%) presented with a significantly higher frequency of this trait when compared to females (18.7%). There was however, a slight but not significant female preponderance in the S.A. white sample.

7. **Bipartite Superior Articular Facets of the Atlas**

Bipartite superior articular facets of the atlas were present more often in S.A. whites (25.0%) than S.A. blacks (15.3%) and in males (both black and white) more than females. The trait also tended to be present more often bilaterally than unilaterally. None of these differences were however significant.

8. **Posterior Bridge of the Atlas**

A complete posterior bridge of the atlas was present more frequently in the S.A. black sample (14.7%) than the S.A. white sample (10.0%). Black males tend to present with this trait more frequently than black females. The bilateral expression of the trait was present more frequently than the unilateral condition. The formation of the bridge is most likely to be due to the ossification of the posterior atlanto-occipital membrane.

9. **Ossification of the Apical Ligament of the Axis**

The S.A. white sample (18.0%) had a higher frequency of ossification of the apical ligament of the dens of the axis than the S.A. black sample (10.7%). There was, as with the posterior bridge of the atlas, a male preponderance for this trait. There is a tendency for an "excess bone" trait, as present in the posterior bridge of the atlas and ossification of the apical ligament of the axis to be more common in males and a "lack of bone" trait to be more common in females.

10. **Variability at Junctional Areas**

Junctional areas are characterised by transitional features regularly present in vertebrae which are in a process of adopting the features typical of the next region. The potential for variation at such transitional areas is revealed by the many reports of unusual and non-typical features of the vertebrae at junctional areas, as well as variations in the numbers of vertebrae.

Variation at the occipito-cervical region presents as occipitalization of the atlas. This rare condition was not found in the present study.

Variation at the cervico-thoracic region was evident in this study by the presence of cervical rib on C7. Kühne (1932 cited by Allbrook, 1955) suggested that the trait was evidence of cranial variation. His study included all junctional regions and he concluded that shifting of intersegmental borders as well as variation in vertebral numbers had a genetic basis. Bornstein and Peterson (1966) and the study of de Beer Kaufman (1974) provided evidence that variation in numbers of presacral vertebrae in man may be a specific characteristic of a population group. Thus the junctional areas may be considered as potentially unstable areas subject to genetic and possibly other influences. The finding of a significantly higher frequency

of cervical rib in S.A. blacks than in S.A. whites may be attributed, in part at least, to genetic influences.

Spina bifida occulta was found at both the occipito-cervical and cervico-thoracic regions. The higher frequency of spina bifida occulta in C1 than at the cervico-thoracic region prompted an examination of factors which might be responsible for this increase in variability. The atlas is unique among vertebrae in having no spine and this was tentatively suggested as being a point of instability. The transitional region in C1 between skull bone and vertebra could be an additional source of possible variability since succeeding junctional areas are between vertebra and vertebra. In addition, there is an alternative pattern of ossification in the posterior arch of C1 which, if present, differs from the pattern in succeeding cervical vertebrae.

11. **Sex Differences**

Although no sex differences were detected for a reduction in number of cervical vertebrae, workers who studied total presacral vertebrae (PSV) (Bornstein and Peterson, 1966, de Beer Kaufman, 1974) reported a tendency towards an increased frequency for 25 PSV in males and a decreased frequency for 23 PSV in females. It is thus suggested that numbers of cervical vertebrae be examined in conjunction with the rest of the spinal column in this regard.

A significantly higher frequency of cervical rib in males was present in two black South African studies (present study, males - 9.3%, females - 2.6%; Asvat and Fell, (1990), males - 2.2%, females - 0.9%). This male preponderance in S.A. blacks was in contrast to studies on other groups (a European and an American white group) where there was a female preponderance of over 70%. It is suggested that this significant male preponderance in the two S.A. black samples may be a characteristic of the S.A. black group.

A female preponderance in the occurrence of spina bifida occulta was present in both black and white S.A. groups and has been reported in studies in the literature. Thus a female preponderance is present for this trait irrespective of population group.

In the atlas vertebra, there was a male preponderance for the presence of both bipartite foramina transversaria and bipartite superior articular

facets in the S.A. black sample. In the smaller white sample however, there was a female preponderance for these traits.

There was a male preponderance for the "excess bone trait" of ossified apical ligament of the axis in both black and white groups and in the black group only for a complete posterior bridge of the atlas. These results follow the patterns reported by Ossenfort (1926) and Corruccini (1974) that hyperostotic bone traits are more common in males.

In general, there was a low degree of sexual dimorphism for most of the traits examined in this dissertation. The only significant male/female differences were those for cervical rib and bipartite foramina transversaria, where the frequencies were higher in the S.A. black male group. A female preponderance of spina bifida occulta was present in both S.A. black and white groups. This female preponderance has been reported in other population groups.

12. Intergroup Differences

Shore's (1930, 1931) contention that S.A. black skeletons are strikingly variable because they possess a higher frequency of "abnormalities" of the vertebral column than Caucasoid material is supported to the extent that the S.A. black sample shows higher frequencies for the traits of cervical rib and non-bifid cervical spinous processes when compared with the S.A. white sample; indeed the results for cervical rib show a much higher frequency (6.0%) than that of Shore (2.5%). S.A. blacks also had higher frequencies for numerical variation (a reduction in number of cervical vertebrae in one column only) and the posterior bridge of the atlas but differences were small and not significant. The S.A. white sample showed significantly higher frequencies of bipartite foramina transversaria as well as a tendency towards higher frequencies of cervical spina bifida occulta of the atlas. However, there was a tendency for a higher frequency of spina bifida occulta of the cervico-thoracic region (excluding the atlas) in blacks than in whites. Both the traits of bipartite superior articular facets of the atlas and ossification of the apical ligament of the axis were slightly more common in S.A. whites though the black/white difference was not significant.

APPENDIX I

PROCEDURES ADOPTED FOR DATA COLLECTION

Appendix I is an example of a data sheet showing the procedure for the collection of data.

Procedure Adopted for Collecting Data

A.D NUMBER ..... POPULATION GROUP AND TRIBAL DIVISION .....

SEX ..... AGE .....

NUMERICAL VARIATION: (IF SO STATE ADDITION OR REDUCTION)

OCCIPITALIZATION OF ATLAS:		PRESENT
		ABSENT
CERVICAL RIB:		PRESENT - if present is it unilateral or bilateral
		ABSENT
CERVICO-THORACIC SPINA-BIFIDA OCCULTA:		PRESENT - If so state what level/s
		ABSENT
CONFIGURATION OF SPINOUS PROCESSES:	BIFID	Bifurcate (Divergent alae)
		Cleft (Parallel alae)
	NON-BIFID	ACINATE (Pointed and tapering)
		OBTUSE (Blunt ended and squat)
		PEDICULATE (Studlike)
		CLAVATE (Long and clublike)
BIPARTITE FORAMINA TRANSVERSARIA:		PRESENT - If so state what level/s
		ABSENT
SUPERIOR ARTICULAR FACET OF ATLAS:		Single more-or-less oval OR 2 distinct facets separated by groove or ridge
POSTERIOR BRIDGE OF ATLAS:		PRESENT (Unilateral or Bilateral)
		ABSENT
OSSIFICATION OF APICAL LIGAMENT:		PRESENT
		ABSENT

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