University of Tennessee, Knoxville

TRACE: Tennessee Research and Creative Exchange

Doctoral Dissertations

Graduate School

8-1982

Craniofacial Structure, Aging and Dental Function: Their Relationships in Adult Human Skeletal Series

Mark Frances Guagliardo
University of Tennessee, Knoxville

Follow this and additional works at: https://trace.tennessee.edu/utk_graddiss

Part of the Anthropology Commons

Recommended Citation

Guagliardo, Mark Frances, "Craniofacial Structure, Aging and Dental Function: Their Relationships in Adult Human Skeletal Series. " PhD diss., University of Tennessee, 1982.
https://trace.tennessee.edu/utk_graddiss/4038

This Dissertation is brought to you for free and open access by the Graduate School at TRACE: Tennessee Research and Creative Exchange. It has been accepted for inclusion in Doctoral Dissertations by an authorized administrator of TRACE: Tennessee Research and Creative Exchange. For more information, please contact trace@utk.edu.

To the Graduate Council:

I am submitting herewith a dissertation written by Mark Frances Guagliardo entitled "Craniofacial Structure, Aging and Dental Function: Their Relationships in Adult Human Skeletal Series." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Anthropology.

Fred H. Smith, Major Professor

We have read this dissertation and recommend its acceptance:

Richard Jantz, William M. Bass, Patrick J. Carney

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a dissertation written by Mark Frances Guagliardo entitled "Craniofacial Structure, Aging and Dental Function: Their Relationships in Adult Human Skeletal Series." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosphy, with a major in Anthropology.

Fred H Smith

Fred H. Smith, Major Professor

We have read this dissertation
and recommend its acceptance:

William M. Bass

Patrick J Carney

Accepted for the Council:

L Evans Roth

Vice Chancellor
Graduate Studies and Research

CRANIOFACIAL STRUCTURE, AGING AND DENTAL FUNCTION: THEIR RELATIONSHIPS IN ADULT HUMAN SKELETAL SERIES

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Mark Frances Guagliardo
August 1982

ACKNOWLEDGMENTS

It is customary to open the acknowledgments section of a dissertation by recognizing one's committee members, and mine are more deserving than most. However, I shall begin with my parents, Frank Guagliardo, Jr. and Fay Ann Tycer Guagliardo, in recognition of the tremendous amount of encouragement and financial support they have bestowed upon me since I entered school. They never pretended to entirely understand my research interests, but the mere fact that I wanted to pursue them was reason enough for my parents to make sacrifices. To my wife, Kathleen Ann Jablonski, I also extend special acknowledgment. As a fellow doctoral candidate in physical anthropology Kathleen jeopardized her own career to marry me. In addition to providing much love and psychological support she assisted by recording data and advising me on innumerable aspects of this investigation.

Few students have been blessed with a doctoral committee as helpful as mine. It would be futile to summarize the types of assistance and guidance that I have received from my friend and chairman, Dr. Fred H. Smith. He has given unselfishly of his time and intellectual resources, and has done all that a student could ask. The rationale of the statistical approach used here was pioneered in craniometrics by Dr. Richard L. Jantz, who patiently explained it to me and helped me clarify my thoughts on many occasions. Dr. William M. Bass, who has been especially supportive of my graduate studies, made his library and many material resources available to me. He also extended permission for me to use the Larson skeletal collection (excavated under National Science Foundation contracts GS837 and GS1635, and National Geographic Society contract 699,912), and the Sully collection (excavated as part of the Smithsonian's River Basin Surveys). Dr. Patrick J. Carney provided valuable assistance with the manuscript preparation, and made special arrangements to accommodate some of my needs.

Very special thanks are due Dr. W. W. Howells of Harvard University. He graciously allowed me to use his craniometric data for four of the five samples studied here, and granted me access to the Yauyos crania housed at the Harvard Peabody Museum. Dr. Howells also made comments on a preliminary study, and provided encouragement through his ever so prompt correspondence.

My fellow Ph.D. graduate and friend, Patrick J. Key, was helpful enough to be considered a co-worker. The Larson cranial measurements used here are those he obtained for his own dissertation. His skills in computer programming are evident from the acknowledgments in Chapters IV and V. Interactions with Dr. Key and especially Dr. John Philpot greatly enhanced my knowledge of statistics.

I am grateful to the following institutions and individuals for allowing and assisting in the collection of tooth wear data from their skeletal materials: Dr. Erik Trinkaus of Harvard's Peabody Museum, Dr. Ian Tattersal of the American Museum of Natural History, and Dr. Douglas H. Ubelaker and Dwight Schmidt of the Smithsonian's National Museum of Natural History.

The following persons assisted with references, illustration tips, and various insightful suggestions: Kathleen Abbott, William Baden, Dr. Rolf Behrents, Tim Bromage, Henry Case, Keith Condon, Terry Falkner, Gary Heathcote, Dr. Robert J. Hinton, Michael Jablonski, Dr. Douglas W. Owsley, Maria O. Smith, and Dr. Patrick S. Willey.

In addition to my parents, financial assistance was obtained from the following, in descending order of contribution size: the Hilton A. Smith Graduate Fellowship program, my brother, Robert E. Guagliardo, Dr. William M. Bass, and a Sigma Xi Scientific Research Society Grant-in-Aid. The data were analyzed with The University of Tennessee Computing Center facilities.

The final manuscript was typed by Margaret Garrett.

ABSTRACT

Five human skeletal series were examined to discern if post-adolescent aging, as measured by dental attrition, has significant effects on the morphometrics of the skull. Definite age-related changes were found in the crania of the European, Melanesian and Arikara Indian collections studied. A statistical approach unique to the subject area showed that both size and shape of the adult skull changed with age. Some of the more pronounced aging effects included forward projection of the face, widening of interorbital dimensions, flattening of the frontal bone in profile, retraction of the subnasal region relative to the zygomatic bones, and increases in orbit size and mastoid size.

It was assumed that dental attrition not only reflected age, but also the cumulative dental functional forces exerted upon the cranium up to the time of death. Thus, after a consideration of craniofacial biomechanics, it became apparent that many of the age changes were probably direct responses to the aggregate forces of biting and chewing.

The results provide support for the theory that some aspects of fossil hominid cranial morphology are adaptations to high levels of dental functional stress and strain. A good case is also made for the possibility that adult aging effects, regardless of their cause, can be a source of noise in some traditional kinds of craniometric investigations.

TABLE OF CONTENTS

CHAPTER PAGE

V. (Continued)

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The study of age changes in the human adult head holds considerable potential for biological anthropology. Clark Wissler (1927:434) introduced an early paper on the subject as follows:

> Yet all the observations so far recorded are in the nature of pioneer efforts and the intense exploration of adult age changes is still for the future; it is moreover an innovation, running counter to deepseated assumptions, and so invites further pioneering exploration, which is the justification of this paper.

Aleš Hrdlička (1936:897) similarly concluded a later publication:

> It is further evident that (adult) age changes, . . . may obscure, or even exceed group or racial differences. This means that henceforth thorough attention, in all anthropometric procedures on the adult, must be paid to age, and that much of the anthropometric work on the adult of the past must be replaced by more selective and critical observations.
>
> This furnishes a vast renewed field of Anthropology. It brings the appreciation that we are still largely in the infancy of the science of man, and that there lies, while laborious, a wonderful future before this branch of endeavor; the fruits of which, moreover, must eventually be not only of academic but also of medical and other practical importance.

There are two ways to view these bold statements. They may reflect the premature excitement of scientists of a naive generation, or they may be seen as truly insightful notions for their time--and ours. The present investigation was begun with the hope that the latter view is the correct one.

Since these earlier reports the study of post-adolescent craniofacial changes has rarely if ever been viewed as a distinct or significant subarea of physical anthropology. There is a very logical reason for this. It is instinctive for even the specialists among us to assume that the skull does not change once human growth "stops" in the early twenties or thereabouts. The difficulty of identifying an old person in an early adulthood portrait does not seem to stem from size or shape changes in the bony support-structure of the face (with the possible exception of localized changes due to tooth loss), but rather from fleshy changes--hair loss and discoloration, wrinkling, freckling, and growth of the external nose and ears. It is therefore equally natural to assume that even if changes in the adult skull do occur they are insignificant.

In spite of this natural assumption there has been a gradual but quiet accumulation of literature on the continued growth of the adult skull and the head in general. The regrettable truth is that a number of problems, ranging from poor sample sizes to improper research designs, have plagued these studies. All that appears to be certain is that alterations in the skull do occur after puberty, and that the most obvious change is resorption of alveolar bone whenever teeth are lost. Many basic questions remain, a few of which are: What parts of the skull change? Are the changes primarily in the size or the shape of the cranium? Are adult age changes gradual or do they unfold in a discontinuous pattern? To what extent do the sexes differ in the manner and degree of post-adolescent growth or degeneration? Finally, what are the causes of these changes?

This investigation has two related goals. One is to improve our understanding of the nature of human adult cranial growth and development. Hopefully this will be accomplished through the examination of both sexes of more than one racial group, and through the implementation of a research design that is unique to this field of study.

The other aim of this research is to explore the hypothesis that some of the age related variation in cranial form discovered is attributable to the cumulative effects of the stresses and strains of dental function. It is well established that living bone is morphologically responsive to the biomechanical forces exerted upon it (Hinrichsen and Storey 1968). Because the major biomechanical activity of the skull is biting and chewing, and because human bite forces can exceed 300 pounds (Hylander 1977a:140) it is reasonable to expect covariations between bite force vectors and cranial morphology.

This study does not attempt to demonstrate that between-population variations in cranial morphology are sometimes best explained in terms of purely genetic adaptations to varying kinds and degrees of dental activity (cf. Hylander 1977a). Rather, cross-sectional samples of skeletal series will be examined in order to determine if there is a statistically detectable amount of within-population cranial variation attributable to age-at-death variation. Patterns of age variability in craniometrics so discovered will be carefully inspected to see if they might best be explained as developmental characters, i.e. variations resulting from interactions between heavy biting and chewing, and the genetic constitution of the individual.

It is reasonable to assume that the extent of dental attrition reflects, among other things, the cumulative amount of dental activity that has occurred (P. Smith 1976; Hinton 1982). Dental attrition also reflects the age of an individual (Miles 1963). Because it is a rough measure of both of the factors of interest here, age and dental function, tooth wear will be used to assign skulls to categories of age-at-death. Once these age category assignments have been made the effects of aging upon skull morphology will be tested statistically. The determination of whether or not dental activity is involved in aging will be a more subjective process. For this it will be necessary to rely upon a knowledge of craniofacial anatomy and masticatory biomechanics. If any morphometric age changes appear to be adaptive or degenerative responses to dental force vectors, such will be given due attention in the discussion.

There are some readily apparent benefits that may accrue from a more complete understanding of adult craniofacial changes, regardless of what agents bring them about. One is in the clinical realm. Orthodontists and orofacial surgeons might be better able to plan corrective treatments of abnormalities and injuries by taking into consideration normal adult growth trajectories in the skull. Anthropologists studying craniometric variation might better design their research strategies. For instance, one who is cognizant of age variation but interested only in sex discrimination could choose to work exclusively with cranial measurements that are unaffected by aging after puberty. Or, analysis comparing crania from several archeological sources might best be done only with skulls of approximately the same age at death. Such strategies could reduce by one the numerous sources of noise now inherent in investigations of archeologically derived crania (e.g. measurement imprecision, incorrect sexing, postmorten warping).

The findings of this study may also have relevance for the interpretations of fossil hominid cranial morphology. Brace and Montagu (1977), Brose and Wolpoff (1971), Smith and Ranyard (1980), Wolpoff (1980) and others view many fossil hominid craniofacial features as genetic adaptations to the rigors of heavy biting and chewing forces. Credence will be lent to these interpretations if it can be shown that bite force is a reasonable explanation for some of the age related craniometric variability in the modern humans studied. The reasoning is that if the influence of dental function forces is important in the ontogenetic development of a single generation then genetic adaptations to those same forces could be developed and maintained over many generations through natural evolutionary forces.

The following chapter will provide the reader with the background necessary to appreciate the state-of-the-art in adult cranial age change studies, the effects of force on cranial and facial bones, and the advantages of the analytical methods used herein. Chapter III provides archeological, ethnological and technological information on the peoples from which the cranial series originated. The next two chapters present the methods of data collection and preparation, and the statistical procedures followed. The results of the statistical analyses are presented in Chapter VI, but with little interpretation. The implications of the results are thoroughly discussed in the seventh chapter, where suggestions for future studies are also made. Concluding remarks are reserved for the final chapter.

CHAPTER II

BACKGROUND

A. ADULT AGE CHANGES IN THE HEAD AND SKULL

A number of factors can contribute to the expression of variation in skull morphology within a human breeding population. These include normal genetic variation between individuals and between family lines (Arya et al. 1973; Harris 1973; Nakata et al. 1974), congenital abnormalities (Kreiborg et al. 1978), and nutritional inequities (Price 1939). This section summarizes the literature on post-adolescent age changes in head and skull dimensions in order to show that the aging process is another factor responsible for morphological variety within a group. Secondarily, this review should demonstrate some inadequacies in previous work on the subject.

Studies on Skeletal Remains

The report of Todd (1924) is perhaps the earliest study of adult age changes using skeletal material. Among hundreds of white male skulls he found cranial thickness at several sites to increase with age. Several years later Hellman (1927) published a frequently cited study of American Indian skulls. It was his impression that bizygomatic breadth and facial height increased in adulthood until the teeth were lost, at which time these dimensions decreased. Other early studies were made by Hrdlička (1935; 1936). He felt that among Pueblo and other Southwestern American Indians head length, head and facial breadth, and head and facial height all increased into old age.

Following Hrdlička's reports there is a long hiatus in the literature on studies of skeletal remains. In 1980 Ruff published a very interesting study on the adult crania from the Archaic site of Indian Knoll, Kentucky. He divided 136 male skulls into two age groups and used 16 measurements on each cranium, taken by Snow (1948). Using t-tests, Hotelling's T^2, and discriminant function analysis he concluded that cranial base length, cranial height and bigonial breadth contribute most to the distinction between age groups, with possible contributions from frontal bone chord, cranial length, basion-prosthion length and bizygomatic breadth. Because the present study also uses multivariate statistics and skull measurements, special effort will be made to discern parallels between Ruff's results and those of Chapter VI, below.

Ruff (1980) was also interested in whether age group differences were due to changes in skull size or shape. Therefore, as a post-hoc procedure he corrected for all the data for size effects using Corruccini's (1973; 1976) method. He then recomputed the T^2 value and found that it was not significant. Age effects therefore appeared to be almost exclusively expressed through changes in skull size.

The most recent study of skeletal remains is that of Droessler (1981). She analyzed a large number of craniometric variables taken from Illinois River Valley Amerindian skulls. Though she reports that a few measurements are significantly affected by the adult aging process the impression here is that she found no more statistically significant age changes than would be expected by chance alone.

Cross-sectional Studies on the Living and Cadavers

Like the skeletal studies reviewed above, the reports covered in this section are of a cross-sectional nature. That is, adults of varying ages were measured only once and compared to each other, as opposed to the superior longitudinal studies where persons are measured more than once and the data of the various measuring sessions compared. However, the obvious advantage of the studies in this section over skeletal studies is that there is a more secure knowledge of the sex and populational origin of the persons examined.

Perhaps the first study of adult age changes in the human head was that by Parchappe (1836; cited in Hrdlička 1936). Though his sample sizes and methods were rather poor he found that head size increased in French men up to age 50. Near the turn of the century Pfitzner (1899; cited in Hrdlička 1936; Isreal 1973a; and Lasker 1953) studied a series of 3,400 Alsatian cadavers--all adults. He too reported that the head and face increased in size, but the breadth-height index of the head decreased and morphological face index decreased as aging progressed.

Hrdlička (1925) studied age group differences in adult white American males and females, as did Wissler (1927) for native Hawaiians. Head length, width and height, and facial height were reported to increase with age, although some reductions were noted later in life, and the sexes and races were not identical in their patterns of continued adult head growth.

Unlike most other studies Goldstein (1936) found reduction of head dimensions to be the norm rather than the exception. Most facial heights and all of his facial width and depth measurements were lower in his older groups of American Jewish males. The apparent novelty of these findings stems from the fact that his investigation compares extremely old to very young adults, while most other studies concentrate on age changes before the seventh decade in life. It is possible that cranial and facial bone dimensions decrease in senility as Goldstein (1936) claims.

Tens of thousands of young white Army males were examined in a cross-sectional manner by Randall (1949) for age changes in anthropometrics. He felt that head circumference changed very slightly over this age period but did show an increasing trend.

The next year Coon (1950) published a study of the adult males of the mountain-dwelling Ghegs of Northern Albania. He concluded that head breadth gradually increased to the early-middle forties and then decreased. In addition, bizygomatic breadth increased until the late forties while total facial height continually increased throughout life. From the trends of these latter measurements Coon (1950:74) conjectures, "This means that our Mountain Ghegs may owe part of their greater face length, and breadth, over other European series to their more advanced age." This statement should be considered with caution, but it is this kind of thinking that helped foster the present investigation. Perhaps age effects can interfere with our ability to discern population affinities.

Several other studies were published in the decade following Coon's report. Among Mexican villagers and migrants Lasker (1953), and Lasker and Evans (1961) found age related increases in some head height and facial breadth measurements, while some facial variables decreased. Baer (1956) analyzed data from thousands of young white male and female Army personnel between 19 and 33 years of age. He reported that only parts of the face grew, but that cranial measurements were unchanged by age. Interestingly Baer did regressions of each variable on age and found that second degree polynomials fit the face and nose height data better than a straight line. This means that some head dimensions in some populations may not continue to increase at a constant rate in adulthood.

In addition to presenting an improved methodology (i.e. large samples analyzed by analysis of variance and regression) Baer (1956) explicitly outlined some important considerations that should be made for all cross-sectional studies of adult aging, whether they be of skeletons or the living. He identified three sources of age group variability: (1) true ontogenetic changes within individual adults, (2) secular trends in adult morphology, and (3) selective survival (i.e. natural selection for particular head morphology within each generation). The latter two sources do not seem to be very likely agents of variability, but we should remember that many people hold the same view of normal adult ontogenetic changes. Even the slightest sources of noise may disguise age variability and investigators must be aware of Baer's warnings when designing studies such as the present one.

A number of cross-sectional studies, most using measurements from lateral head radiographs, were published in the 1970's: Howells and Bleibtreu (1970), Israel (1973b, c), and Lewis and Roche (1977) on

American whites; Adeloye et al. (1975), Nasjleti and Kowalski (1975), Kowalski and Nasjleti (1976), and Harris et al. (1977) on American whites and blacks; Colby and Cleall (1974), and Cederquist and Dahlberg (1979) on Eskimos. The studies variously reported age changes or stability in the cranial base and gonial angles, frontal sinus and sella turcica fossa size increases, skull thickness increases, cranial facial, and mandibular size increases, facial depth reduction, and stability or sometimes change in certain indices of cranial and facial measurements.

Longitudinal Studies

These kinds of investigations are far superior to those previously reviewed but, for practical reasons, are much more difficult to execute. Since Buchi's (1950) pioneering study of age changes there have been a number of other reports of longitudinal investigations (Thompson and Kendrick 1964; Kendrick and Risinger 1967; Carlsson and Persson 1967; Carlsson et al. 1967; Israel 1967; 1968; 1977; Tallgren 1974; Susanne 1977). Unfortunately these studies are on Caucasians only. In addition most of them use measurements from lateral head radiographs and this affords only a limited coverage of skull morphology.

It appears from these reports that numerous common measurements of cranial and facial size increased with age as did cranial bone thickness. Alveolar height and width were seen to decrease (Carlsson and Persson 1967; Carlsson et al. 1967). However, to demonstrate the lack of complete harmony among these findings it should be noted that

Tallgren (1974) concluded that adult age changes in craniofacial morphology were insignificant if they occurred at all.

Summary of Age Change Studies

Most of these studies have concerned Caucasians, with a few on blacks and Native Americans. This can present to us only a narrow range of human variation with respect to adult age changes in the skull, and points to the need for examination of other groups.

We have seen reports that sexes are similar, and that they are different in their patterns of age variability. Sometimes the rate of adult age change in the skull is said to be gradual but continual, and sometimes it is said to be more rapid at certain ages. It appears that vertical and lateral dimensions of the head are more often affected than anterio-posterior measurements. Those dimensions that do change usually increase with age, though reductions may occur in senility. Some reports suggest that the various parts of the skull change so as to maintain a constant skull shape, while others disagree. One publication (Tallgren 1974) even suggests that there are no changes at all. Because of the inconsistencies among these reports the present research is pursued without a priori hypotheses about how the skull should change as it ages.

The investigations reviewed all have their problems and this may partially explain their inconsistencies. Anthropometrics of the living and cadavers do not accurately reflect skeletal changes because some unknowable portion of each measurement is flesh. On the other hand studies of skeletal collections can, of course, never be longitudinal in design. Measurements on head radiographs would seem to be a a satisfactory solution, but such investigations have for practical reasons always been limited to one view of the skull--the lateral view, which only affords measurements of the mid-sagittal plane. This allows a very inadequate coverage of the skull. The present research involves only skeletal material, and will be pursued with the understanding that the cross-sectional nature of the data makes this study less than optimally sensitive to age changes in the skull. However, what is lost in this manner will hopefully be made up by the use of a large number of measurements on each skull.

The reviewed studies variously suffer from other problems. These include small sample sizes, examination of a narrow age range, and small numbers of measurements. A very common shortcoming is the use of univariate statistical tests, if any statistical analyses are done at all. The few multivariate studies establish very securely that changes do occur. However, because skull measurements are so highly intercorrelated these reports have not been satisfactorily able to designate in what ways the adult skull ages. The following chapters outline an investigative approach which will circumvent most of these pitfalls.

B. EFFECTS OF FORCE ON CRANIOFACIAL BONES

Many experiments on animals have certified that development of craniofacial bones, and hence adult skull morphology, is influenced by muscular activity about the growing skull (Pratt 1943; Washburn 1946; 1947a, b; Horowitz and Shapiro 1951; Watt and Williams 1951; Moss 1957; Moore 1965; Beecher and Corruccini 1981). These findings have not escaped the attention of physical anthropologists. In fact, as early as 1910 Hrdlička realized the important role that powerful bite forces could play in shaping the face and cranium. However, when the issue receives attention in the anthropological literature it is usually in the context of discussions on evolutionary adaptations (e.g. Hrdlička 1911; Weidenreich 1941; Coon 1950; Brace 1963, 1964; Brose and Wolpoff 1971; Wolpoff 1980).

It is not surprising that there have not been any experimental studies specifically designed to test the effect of force on adult human craniofacial form. Still, there have been those who recognize, implicitly or explicitly, the influence that the masticatory complex can exert on human skull development (Hrdlička 1910, 1940; Leigh 1928; Moss and Young 1960; Oppenheimer 1964).

Hinton (1979, 1981a, b; 1982) has examined the relationship between dental occlusive forces and morphology of the temporomandibular joint in a number of skeletal samples. He presented conclusive evidence that a significant amount of adult morphological variation in at least this area of the skull is attributable to the cumulative amount of chewing forces transmitted through the joint. Incidentally, Hinton used dental attrition as a measure of the amount of dental activity his specimens had experienced by the time of death. Therefore, his findings suggest that the present investigation, which uses dental attrition for a similar purpose, has some promise of revealing relationships between dental function and skull morphology.

Hrdlička (1936) presented an interesting discussion as part of a study of continued growth of Southwestern American Indian crania.

In regard to his finding that facial height and breadth increased with age Hrdlička (1936:875) stated that:

> The adult facial growth may correlate with similar growth in the vault of the skull; or it may be the result of the work performed by the apparatus of mastication. Both perhaps are involved. The matter will need special investigation on most suitable materials.

Also of relevance here is his feeling that:

> It is not certain with a series of white people that their masticatory habits or exertions have not changed in the course of time and affected the facial dimensions. Such a gradual change would certainly take place in a transit from a less to more cultural condition of a people and that probably in a very few generations (Hrdlicka 1936:871).

In spite of his reference to "the course of time" Hrdlička clearly recognized the importance of dental function in the ontogenetic development of the adult skull.

The results of another adult age change study have relevance to the question of the effects of dental functional force on bones of the skull. Carlsson et al. (1967) noticed that persons without lower anterior teeth or lower anterior dentures experienced a faster rate of alveolar bone resorption than those with teeth or dentures. Perhaps normal mechanical force is necessary to maintain normal morphology of the alveolus. There is no reason to believe the same is not true for all craniofacial bone tissue.

A unique and well researched article was published by Kokich (1976). His primary interest was in adult age changes in the frontozygomatic suture and their causes. His histologic, radiographic, and gross examination of 61 presumably Caucasian cadavers suggested that: (1) at all ages the periostial surface of the eye orbit around the suture was resorptive in the vicinity of the frontozygomatic suture; while (2) the adjacent facial surface is appositional. Kokich feels that these findings explain why so many studies of adult aging report increases in bizygomatic breadth. He also found (3) progressive enlargement of the marrow cavities of the zygomatic and frontal bones, and (4) an increasing complexity of sutural interdigitation. Concerning this last finding Kokich (1976) cites evidence that sutural complexity reflects the amount of extrinsic force (e.g. bite force) that has been applied to the suture (Washburn 1947a; Moss 1957, 1961). If cumulative extrinsic forces can produce progressive sutural complexity, as all of this suggests, then perhaps such forces can alter metric characters of the skull as a person ages.

Hunt (1959) published a frequently cited discussion of the effects of vigorous chewing on the facial growth of Australians. Although he emphasized the involvement of dental attrition and bite force in the production of jaw size and dental occlusive alignment, he also proposed a theory to explain why Aboriginals have vertically shortened faces and wider palates than many other races. Hunt suggested that the tremendous, albeit typical, amount of dental occlusal forces transmitted through the faces of non-Westernized aboriginals actually stunted growth at the sutures of the upper face, and stimulated growth at the mid-palatal suture. Care will be taken to discern if there is any support for this theory of facial development in the results of Chapter VI.

C. SOME CONSIDERATIONS ON DENTAL ATTRITION

The wearing away of dental tissues has sometimes been referred to as abrasion and sometimes as attrition. To some researchers one term means wear caused by tooth-to-tooth contact, while the other connotes wear due to course substances in the diet. However, there is a lack of consistency in the literature as to which term has which meaning (e.g. compare Dahlberg 1960 with Leigh 1925a, b). There are many authors who make no distinction between the two (e.g. Brothwell 1972), or who use one or the other term to refer to any kind of tooth wear (e.g. Bodecker 1925; Goose 1963). Therefore, throughout this report the designations wear, attrition, and abrasion will be used interchangeably.

There are a number of ways to view the meaning and, therefore, the use of dental attrition. It has been employed as an estimator of age-at-death (Miles 1963), or an indicator of diet content (Walker et al. 1978) and technological sophistication (Brace and Mahler 1971; F. Smith 1976a). Dental attrition has also been used to explain intra- and inter-population variation in dental arch dimensions (Hylander 1977b) and types of dental occlusion (Barrett 1958; Wolpoff 1971).

This study uses tooth wear primarily as a device to categorize crania into age-at-death intervals. However, some of the interpretations made of craniometric differences between age groups will be based upon the assumption that dental attrition can be used as a rough indicator of the aggregate amount of bite forces that the teeth had exerted. As succinctly stated by P. Smith (1976:140), "The pattern and severity of dental attrition provide an excellent record of the functional load carried by the teeth."

Only the studies by Hinton (1979; 1981a, b; 1982), reviewed in the previous section, have used dental attrition in a way similar to this investigation. He found in several skeletal series that as tooth wear progressed the depth and slope of the mandibular fossa decreased. Hinton convincingly interpreted these morphological changes as responses to the cumulative effects of dental function. However, he recognized that the effects of cumulative dental function (as measured by attrition) and of normal physiological aging were hopelessly confounded. In other words, it would have been inappropriate to say categorically that mandibular fossa morphology would not have changed with aging, regardless of what levels of dental activity were realized. Thus Hinton (1981a) speaks of "functional age" effects rather than age effects or cumulative dental function effects.

The research design presented below suffers from the same problem. If the age-at-death of each skull could be assessed independently of dental attrition then statistical techniques (e.g. analysis of covariance) could be used to test for the independent effects of age and dental function upon cranial morphology. The better adult aging methods available to skeletal biologists include the counting of osteons in long bone cross-sections (Kerley 1965), and the scoring of pubic symphysis morphology (McKern and Stewart 1957; Gilbert and McKern 1973). Osteon counting was impractical here because of costs involved, as well as the fact that most skulls used in this analysis did not have associated postcranial remains. The pubic symphysis aging method could not be effectively used for the latter reason; there is also some question as to its reliability (Suchey 1977).

A number of colleagues have suggested the use of some method similar to those of P. Smith (1972) or Scott (1979), which assess the rate of tooth wear independently of age. In this way craniometric comparisons could be made between groups of persons of a similar extent of wear but different wear rates. Unfortunately, sample sizes would not allow such an involved analysis, as will be seen later.

Finally, some consideration should be given to the sources of "noise" that come into play any time tooth wear is used to categorize skeletons for any reason. Molnar (1972) presents a thorough literature review that outlines numerous causes of interpopulation variations in the extent, rate and pattern of tooth wear. This is not a problem here because analyses will be done only within populations, not between them. However, there are, theoretically, a number of sources of within-population variability in attrition. For instance, individual variability in food selection (Kennedy 1972) may lead to differences in the amount of grit in the diet. Grit can easily increase attrition without an appreciable rise in chewing muscle exertion. Still, any such source of "noise" will more likely lead to an acceptance of the null hypothesis of no association between wear and craniometrics, than to the false conclusion that such an association does exist. In other words, it is all the more remarkable if skulls classified into stages of attrition show significant morphological differences in spite of noises that may be in effect.

CHAPTER III

SKELETAL SAMPLES USED

A. INTRODUCTION

Several times in these pages the point will be made that large numbers of very well preserved adult crania of both sexes are necessary for a study of this type. This should have been the major criterion for selection of the groups used. Unfortunately, there were other equally important considerations. The crania used had to be accessible to the author (i.e. housed in the continental United States). It was also felt that the populations from which they were derived should ideally show a significant amount of dental attrition by middle adult and certainly by late adult ages. Thus fine collections of modern peoples such as the Smithsonian's Terry Collection or the Hamman-Todd Collection at Case Western University could not be used.

It was desirable to use collections that were as representative of genetic populations as possible--something akin to Garn's (1971) "microrace" should do. To quote Howells (1973:6) this is necessary, ". . . to maintain the integrity of intrapopulation variation in all groups and to reduce possible environmental effects of drawing skulls from varying backgrounds. . . ." This is in keeping with the purpose of the study, which is to test for effects of age/dental function on intrapopulation cranial variation. Five collections met or nearly met all of these prerequisites and are discussed below in random order.

Additional notes on the Berg, Tolai, Yauyos and Sully crania may be found in Howells (1973), from which parts of the following are liberally paraphrased.

B. BERG

These crania were collected by Felix von Luschan from a charnel house in the mountain village of Berg, on the Drau River in Southern Austria. The American Museum of Natural History obtained them in 1924 as a gift from Felix Warburg. Though there are no published notes attesting to this fact, Shapiro (1929) and Howells (1973:13) are confident that the skeletons were periodically exhumed from nearby cemeteries as more burial space was needed, and placed in the charnel house.

> At the time of acquisition (1911), according to von Luschan, the village itself had about 30 houses and had harbored in recent centuries hardly more than 100 souls: he supposed therefore that he had collected virtually all the crania representing some 5 generations of this isolated village's population, excluding only some badly preserved skulls of children (Howells 1973:13).

Von Luschan's notes state that the sample dates from the 17th through 19th centuries. Therefore, the crania may approximate a temporal sample of a lineage rather than a single cross-section of adult skulls at one point in time. In either case there is little chance that outside genetic or cultural influences have had much effect on the expression of cranial variation in this series.

The Berg villagers are the most technologically advanced peoples examined in this investigation. It is unlikely that there was anything about their life ways that would distinguish them much from other Central European mountain villagers of the last few centuries. We can assume that the skeletal sample is composed predominantly of farmers, dairymen, foresters, some craftsmen, and their families (Baring 1817; Keefe et al. 1976). There is no ethnographic literature that addresses the question, but it seems unlikely that these people used their teeth as much in nonmasticatory activities as the other groups studied. Still they were included in the hope that their dental attrition would be apparent enough for them to provide a European contrast to the other populations examined. (See Miles (1963) for evidence that severe wear could develop in Europeans as recently as Anglo-Saxon times, circa 400-1042 A.D.)

C. TOLAI

These skulls originate from the Ralûm region of New Britain in Melanesia. Most of them were collected by the naturalist Richard Parkinson (1907, cited in Howells 1973:24-25), who unfortunately left no records as to how the crania were obtained. It is impossible to say precisely how old the skulls are, but they were apparently collected in 1900 and 1908. Felix von Luschan acquired these from Parkinson and purchased a few others in Sydney, Australia in 1914. Some of these crania are now in the Field Museum of Natural History in Chicago, and have been studied by von Bonin (1936). Others were kept in Berlin's Königliche Museum für Volkerkunde where they were examined by Müller (1905). In 1924 the latter group was given by Felix Warburg to the American Museum of Natural History where they are now kept. It was these that were examined in the present work.

Howells (1973:24) explains that there is nothing in Parkinson's books (1887; 1907) that irrefutably establishes that these crania belonged to Tolai tribesmen. On the other hand there is no doubt that they are from the Ralûm area, and this is Tolai country. The ethnic identity of these skulls was confirmed in 1962 by an old Tolai man who witnessed Parkinson's collections.

Epstein (1968) provides a synopsis of Tolai economics, technology and subsistence strategy, past and present. Through the end of the last century these tribesmen were head hunters and cannibals who not infrequently sold human flesh at markets. Before white contact steel tools were unknown to them (Salisbury 1970:19-20). Sharpened bamboo, stone axes and pointed sticks were their major cutting tools (i.e. those implements most likely to relieve the masticatory system of nonmasticatory tasks.) Though some hunting was practiced the volcanoes of New Britain made the area very conducive to farming. Inland Tolai raised coconuts, yams, taro, sweet potatoes, sugar cane and bananas, and sold these crops to coastal Tolai for fish, eggs, lime and saltwater (Epstein 1968:22).

European settlements were started rather late in New Britain, with the first mission established in 1875. It is therefore unlikely that Western technology had much opportunity to mitigate the effects of dental function upon the crania studied, except to the extent that the Tolai were trading with non-Tolai who, in turn, traded with Europeans.

D. YAUYOS

Of the samples studied the least is known about the Yauyos crania. Yauyos is not a particular village or tribe, but an old Inca province 50 to 100 kilometers southeast of Lima, Peru. Skeletons were collected from this region in the late 1900's by J. C. Tello of Lima's National Museum of Anthropology (Howells 1973:30). In 1911 they were transferred to the Harvard University Medical School, and in 1956 were acquired by Harvard's Peabody Museum where they now rest. Nothing is known of their archeological age, ethnological background, or precise geographical origin except that they probably derive from 16 different sites, hamlets or villages.

Craniometric data for all of the Yauyos crania used by Howells (1973) were available for this investigation. Unfortunately, it was not possible to obtain Peabody Museum catalogue numbers for 12 male and 13 female skulls. Therefore, these skulls were included in the factor analysis of Chapter VI, but were not included in the dental attrition analyses as it was impossible to collect tooth wear data for them.

E. SULLY ARIKARA

The Sully site (39SL4) is located on the Missouri River about 21 miles northwest of Pierre, South Dakota. It was composed of a village, from which some skeletons were obtained, and four other spatially distinct burial areas (Bass n.d.a.; Owsley and Jantz 1978). The skeletons were excavated by William M. Bass in 1957, 1958, 1961 and 1962 as part of the Smithsonian Institution's River Basin Surveys. Some of the remains are now at the National Museum of Natural History, and the rest are at The University of Tennessee Department of Anthropology. Multivariate craniometric analyses strongly suggest that the Sully occupants best be considered Arikara tribesmen (Jantz 1973, 1977). Lehmer (1971) has assigned the site to the Extended Coalescent and Post-Contact Coalescent archeological variants which cover the range of 1550-1780 A.D.

The degree of genetic homogeneity of the Sully people over the full period of site occupation cannot be determined. In fact it is difficult to estimate the length of time the site was occupied. There were probably at least two occupational components. Roberts (1960) states that two distinct house types were found during village excavations, and Bass (n.d.a.) reports that one of the burial areas, D, was partially overlain by subsequent village construction. Area D also yielded a lower percentage of European trade items than the other three areas from which crania are used: A, B, and E. This suggests that component D is earlier than one of the village occupations. Still it is impossible to determine how much older D is than the other burial areas. Weakley (1971) found specific tree ring dates from Sully that range from 1663-1694 A.D., but these are limited to burial area A and the village. Archaeological data such as pit intrusions and grave good associations suggest some behavioral distinctions among the burial areas. The areas may have been temporally different (Owsley and Jantz 1978) though the possibility remains that some were contemporary and only distinguished by clan or family lines.

Most disturbing of all, however, are the findings of Owsley and Jantz (1978). They computed discriminant functions between the burial areas using seven cranial measurements and found that both sexes indicated the areas were significantly different. However, craniometric heterogeneity among the burial areas was not established beyond doubt. The criterion of selecting variables to use in the discriminant analysis biased their results somewhat in favor of finding burial area differences. In addition, the ratio of number of individuals to number of variables was less than ideal. Still, interpretations of age-at-death variability in craniometrics will have to be tempered by a consideration of the multi-component nature of the site. In other words any age differences discovered may be partly attributable to burial area differences in skull form--if such differences exist.

As stated earlier in this chapter, an investigation such as this should use only cranial collections that represent or nearly represent breeding populations or short lineages in order to control for inter-population variation in cranial size and shape. The above information suggests that Sully is not ideal in this respect. This sample is, however, better than the Yauyos and Tolai collections. In summary, the Sully series is probably composed only of Arikara crania, and the precedence set by Howells (1973), Jantz (1977) and Key and Jantz (1981) of treating the series as a single population sample will be followed here, but with caution.

During the late prehistoric-early contact periods, when Sully was occupied, Arikara subsistence activities varied with the seasons: spring was the time for planting, summer for nomadic bison hunting, fall for settled harvesting, and winter for a mixture of activities (Hurt 1969). The Arikara surely used their teeth in many subsistence and non-subsistence activities year-round. This is suggested by their very extensive degree of tooth wear (Butler 1972).

F. LARSON ARIKARA

The Larson site (39WW2) is located approximately two miles southeast of Mobridge, South Dakota, on the east bank of the Missouri River. The site consists of a stockaded village and an associated cemetery. Some of the human skeletal material was excavated from the village area by Alfred Bowers in 1963 and 1964, and by J. J. Hoffman in 1966 as part of the Smithsonian's River Basin Surveys. Most of the skeletons were excavated under the direction of William M. Bass between 1966 and 1968 (Owsley 1975). The skeletons are presently housed at The University of Tennessee Department of Anthropology.

All of the crania are from a single occupation component. Circumstantial evidence had indicated that this occupation ranged from about 1750-1781 A.D. (Jantz 1970; Owsley 1975). However, Jantz and Owsley (1982) have recently learned from Craig Johnson of the University of Missouri (via personal communication) that the Larson ceramic remains date the occupation fairly well at 1679-1733 A.D. In either case this sample is an excellent one for this study because of the large number of well preserved skulls and their cultural and presumed genetic homogeneity.

Owsley (1975) summarizes the arguments in favor of the Larson people's Arikara tribal affiliations. Archeological evidence such as house types indicate that the Larson site belongs to the Le Beau phase of the Post-Contact variant of the Missouri River Valley's Coalescent tradition (Lehmer 1971). The Le Beau phase is most probably Arikara (Lehmer 1971:203). In addition, the mode of interment of the dead at Larson seems to match the protohistoric Arikara pattern (Bass n.d.b.). Support is found in several craniometric analyses (e.g. Jantz 1973, 1977), which clearly place Larson with other known and presumed Arikara as opposed to Mandan, the only other suggested tribal affiliation for the Le Beau phase (Bowers 1950).

During the Larson occupation times had probably improved for the Arikara since the earlier Sully occupations (Jantz and Owsley 1982). Though the general types of subsistence had not changed, the acquisition of the horse circa 1715 (Holder 1970) and improved weather conditions increased food resources considerably.

G. SEXING AND AGING

Howells (1973:7-18, 13, 25, 30) should be consulted regarding sex determination of the Berg, Tolai and Yauyos specimens, and Key (1982) discusses sex determination for the two Arikara series. It should be clearly stated that sex determination was sometimes difficult for the non-Arikara skulls as no postcranial remains and very few mandibles were available. I agreed with the sexes assigned by Howells for nearly all skulls. We disagreed only on cases which were particularly difficult to assign sex. For these few Howells' designation was accepted because of his greater experience with handling the collections. The common availability of postcranial remains from the Larson and Sully crania made sex assessment much easier. Key and I independently assessed each individual using standard techniques such as those outlined in Bass (1971), Krogman (1962), and Phenice (1969). The few specimens on which we differed were reexamined, and mutual agreement was reached on all but one Sully cranium.

Only those judged to be adult specimens were used. For a skull to be used all teeth had to be fully erupted except the third molars (Schour and Massler 1941). If the postcranium was present the individual had to exhibit a large degree of epiphyseal union on most of the long bones available. Particular attention was given to the medial clavicular epiphysis which begins to fuse at 17-18 years of age in white males (McKern and Stewart 1957:91-92). For specimens with no postcranium and without extensive tooth wear, but whose second molars were erupted, experience was relied upon to judge such subjective age-related traits as development of brow ridges and relative size of the face to the calvarium. It is unlikely that more than a handful of the skulls used belonged to persons who died before 18 years of age, and it is extremely doubtful that any specimens used died before the age of 16.

CHAPTER IV

DATA COLLECTION AND PREPARATION

A. CRANIAL MEASUREMENTS AND ANGLES

Regarding the process of selecting the cranial measurements for a study Howells (1973:31-32) feels that the following are not very good reasons to use a variable:

1. the measurement is defined in Martin, etc.
2. "I learned it from my teacher. . . ." "It is in general use in this laboratory . . ." etc.
3. it is needed to compute the cranial (facial, nasal) index.

However, the first excuse is one of the reasons for selection of the measurements in this study: the measurements are defined in Howells (1973:163-190). In fact the data for the Berg, Tolai, Yauyos, and Sully skulls are precisely those collected by Howells and graciously provided to the author for the purpose of this investigation. For the sake of compatability the measurements selected for the Larson group were the same. The entire set of measurements and angles, and their three letter code names are given in Table 1.

The measurement set has important advantages (Howells 1973:31-36; Key 1979:15-19) other than that the data were already collected. No indices, linear combinations of measurements, circumferences, arcs, or estimates of cranial capacity are included. Experience has shown that the information they provide about skull size and shape is for the most part redundant in light of the statistical methods used (Howells 1957; and Chapter V below). The measurement set includes chords,

TABLE 1. CRANIAL VARIABLES AND THEIR CODE NAMES

CODE NAME		VARIABLE
1	GOL	GLABELLO-OCCIPITAL LENGTH
2	NOL	NASIO-OCCIPITAL LENGTH
3	BNL	BASION-NASION LENGTH
4	BBH	BASION-BREGMA HEIGHT
5	XCB	MAXIMAL CRANIAL BREADTH
6	XFB	MAXIMUM FRONTAL BREADTH
7	STB	BISTEPHANIC BREADTH
8	ZYB	BIZYGOMATIC BREADTH
9	AUB	BIAURICULAR BREADTH
10	WCB	MINIMUM CRANIAL BREADTH
11	ASB	BIASTERIONIC BREADTH
12	BPL	BASION-PROSTHION LENGTH
13	NPH	NASION-PROSTHION HEIGHT
14	NLH	NASAL HEIGHT
15	OBH	ORBIT HEIGHT LEFT
16	OBB	ORBIT BREADTH LEFT
17	JUB	BIJUGAL BREADTH
18	NLB	NASAL BREADTH
19	MAB	PALATE BREADTH
20	MDH	MASTOID HEIGHT
21	MDB	MASTOID WIDTH
22	ZMB	BIMAXILLARY BREADTH
23	SSS	ZYGOMAXILLARY SUBTENSE
24	FMB	BIFRONTAL BREADTH
25	NAS	NASIO-FRONTAL SUBTENSE
26	EKB	BIORBITAL BREADTH
27	DKS	DACRYON SUBTENSE
28	DKB	INTERORBITAL BREADTH
29	NDS	NASO-DACRYAL SUBTENSE
30	WNB	SIMOTIC CHORD
31	SIS	SIMOTIC SUBTENSE
32	IML	MALAR LENGTH INFERIOR
33	XML	MALAR LENGTH MAXIMUM
34	MLS	MALAR SUBTENSE
35	WMH	CHEEK HEIGHT
36	SOS	SUPRAORBITAL PROJECTION
37	GLS	GLABELLA PROJECTION
38	FOL	FORAMEN MAGNUM LENGTH
39	FRC	NASION-BREGMA CHORD
40	FRS	NASION-BREGMA SUBTENSE
41	FRF	NASION-SUBTENSE FRACTION
42	PAC	BREGMA-LAMBDA CHORD
43	PAS	BREGMA-LAMBDA SUBTENSE
44	PAF	BREGMA-SUBTENSE FRACTION
45	OCC	LAMBDA-OPISTHION CHORD
46	OCS	LAMBDA-OPISTHION SUBTENSE
47	OCF	LAMBDA-SUBTENSE FRACTION
48	VRR	VERTEX RADIUS
49	NAR	NASION RADIUS
50	SSR	SUBSPINALE RADIUS
51	PRR	PROSTHION RADIUS
52	DKR	DACRYON RADIUS
53	ZOR	ZYGOORBIATLE RADIUS
54	FMR	FRONTOMALARE RADIUS
55	EKR	ECTOCONCHION RADIUS
56	ZMR	ZYGOMAXILLARE RADIUS
57	AVR	M1 ALVEOLAR RADIUS
58	NAA	NASION ANGLE, BA-PR
59	PRA	PROSTHION ANGLE, NA-BA
60	BAA	BASION ANGLE, NA-PR
61	NBA	NASION ANGLE, BA-BR
62	BBA	BASION ANGLE, NA-BR
63	SSA	ZYGOMAXILLARE ANGLE
64	NFA	NASIO-FRONTAL ANGLE
65	DKA	DACRYAL ANGLE
66	NDA	NASO-DACRYAL ANGLE
67	SIA	SIMOTIC ANGLE
68	FRA	FRONTAL ANGLE
69	PAA	PARIETAL ANGLE
70	OCA	OCCIPITAL ANGLE

subtenses and associated angles usually not found in traditional sets. These have been shown to provide shape information not accessible through traditional linear measurements (Howells 1966, 1973; Crichton 1966; Key 1979; Key and Jantz 1981). The angles of the sagittal profile have been particularly important in defining cranial structure and discriminating between groups. These are illustrated in Figures 1-3.

The set also abandons the practice of using two different points, depending on the variable, to measure from the basion area and from the prosthion area (i.e. endobasion vs. basion and infradentale vs. prosthion). Though it may improve replicability of measurement ever so slightly, this practice makes it impossible to accurately compute angles such as PRA, BAA, and BBA in Figures 1 and 2.

The measurements of the Howells set are defined in a way that emphasizes anatomical meaning. For example, bregma is defined so as not to measure from the center of a deep sagittal suture or from a point on a meaningless local deviation of the coronal suture.

Finally, the measurement set is large (p=70) and evenly distributed over the skull. This is important because there were no *a priori* hypotheses about what parts of the cranium are influenced by dental function or the aging process. It may have been useful to add variables to the set to improve coverage of the skull, but considerations of sample size and the multivariate nature of the analysis precluded this. This limitation applies to the mandible, for which the Howells set has no measurements. Most of the skulls examined had no mandible, and this key bone of dental function is not analyzed in the present study.

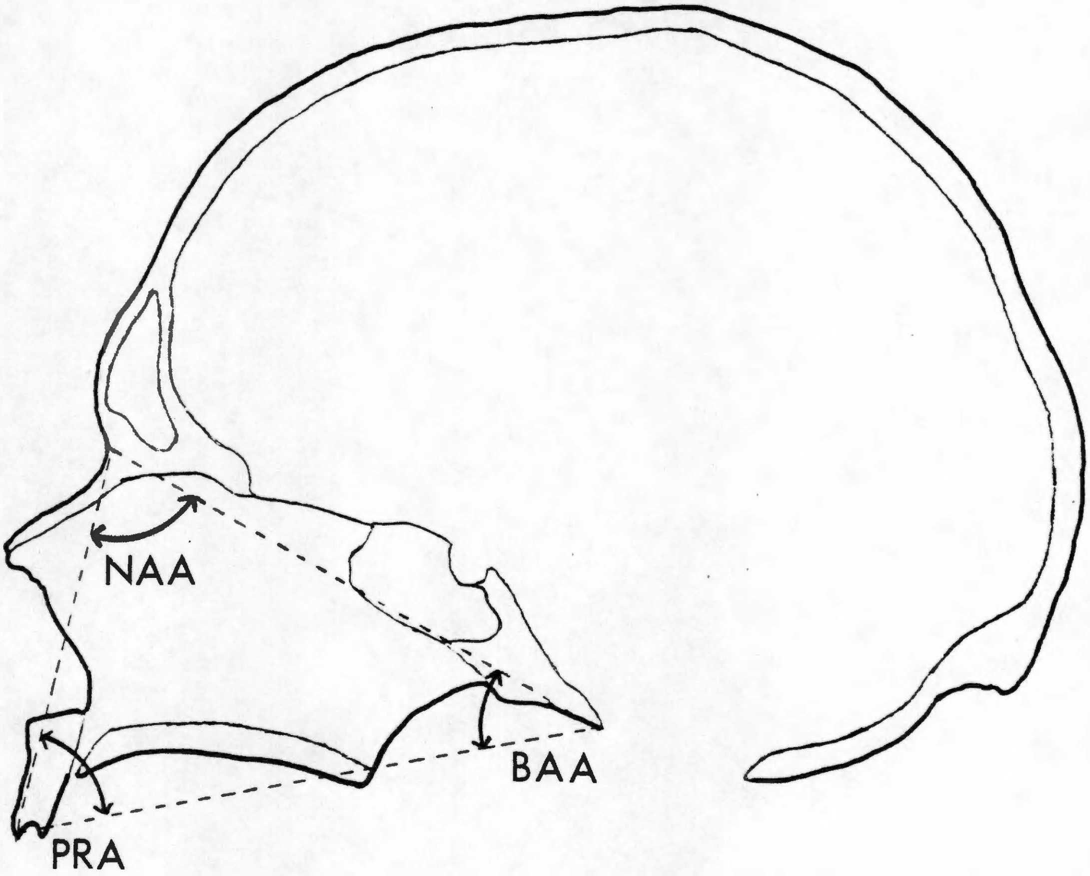


FIGURE 1. ANGLES OF THE FACIAL TRIANGLE

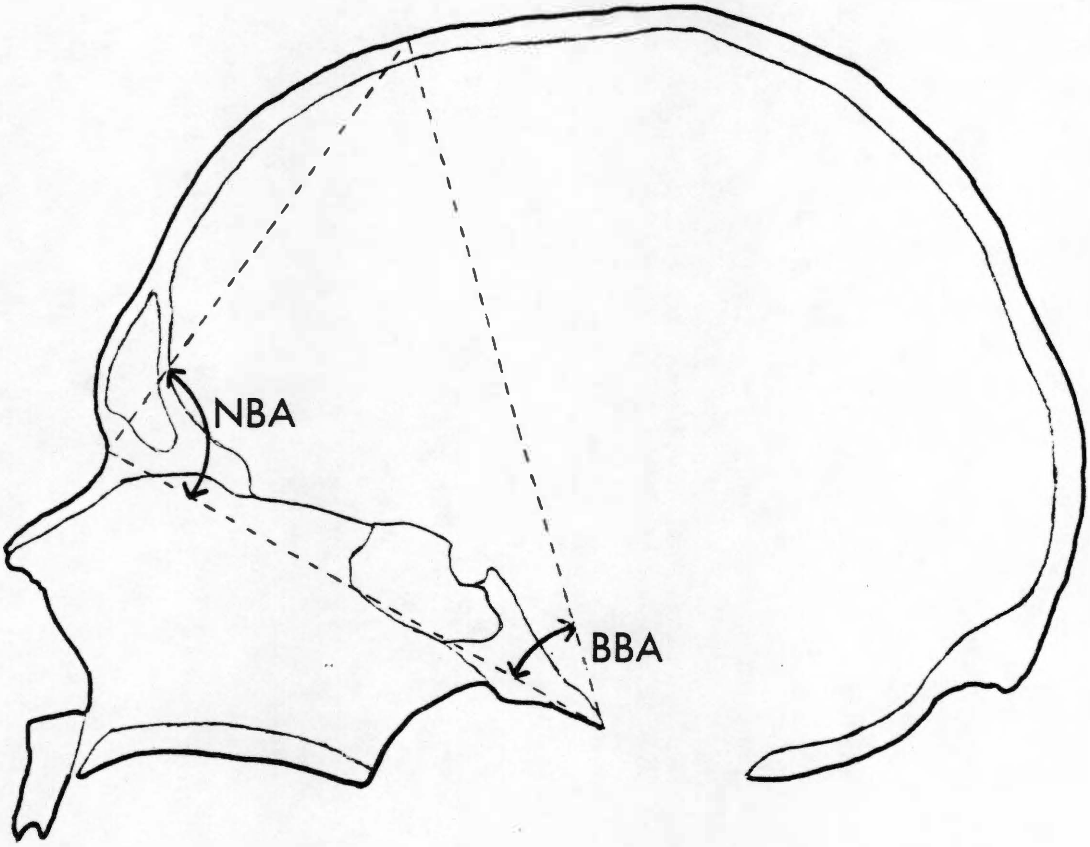


FIGURE 2. ANGLES OF CRANIAL HEIGHT AND FRONTAL BONE LENGTH

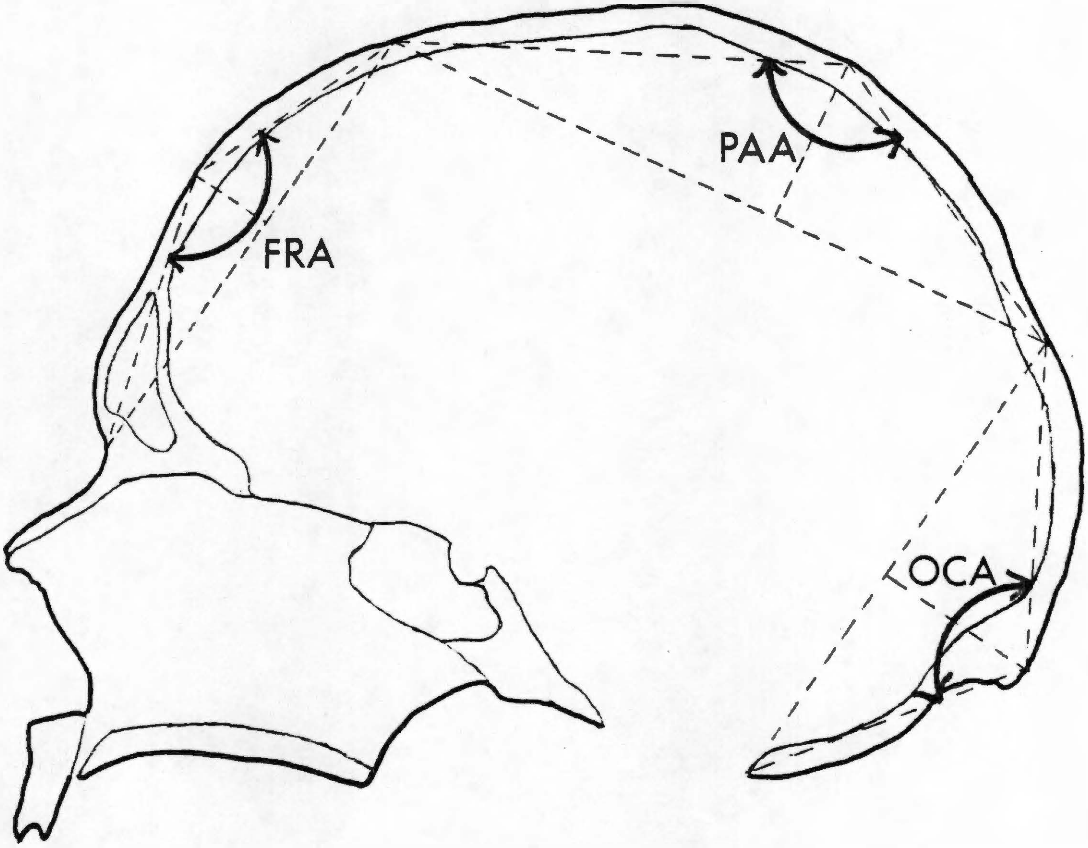


FIGURE 3. ANGLES OF THE FRONTAL, PARIETAL AND OCCIPITAL BONES

The measurements of the Larson crania were taken by Paul Lin (1973) (30 variables) and Patrick Key (1982) (27 variables). The 13 angles were computed from various combinations of these linear measurements by the FORTRAN program, ANGLE, written by Key. The program computes the angles exactly as Howells (1973:187-189) instructs. In addition both Lin and Key took these measurements precisely as explained in Howells (1973:163-190). Key carefully checked Lin's measurements for the 30 variables and found excellent agreement with his own observations. Therefore, there is little concern here over interobserver error in this respect. Both Howells and Key measured the Sully skulls, though Howells' data are used in this investigation. Spot checks revealed exact agreement in most cases between Howells and Key, and no more than 1 mm incongruence for any measurement. It is thus assumed, though not established beyond doubt, that interobserver error between Howells, Key and Lin is negligible.

Multivariate analyses such as those used herein require that every individual has a complete set of measurements. For this reason only well preserved skulls were measured. However, both Howells and Key occasionally found it necessary to estimate one or a few measurements on a skull in order to achieve a reasonable sample size for a particular skeletal series. For skulls used in the present investigation no measurements were estimated by multivariate statistical methods (cf. Key 1982). Approximations were done with the measuring instrument in the presence of the skull, and only estimates made with a good degree of certainty were recorded (Howells 1973:33-35).

The descriptive statistics of the cranial measurements were computed and printed in tabular form by the DISTAB program (Key 1979). The results for each sex of each of the five skeletal series are reported in Tables A-1 through A-10 in the Appendix.

B. DENTAL ATTRITION SCORING

An ideal dental attrition scoring method should use as many dental elements as possible, thus allowing the best possible overall estimate of the effects of dental function on cranial variation. Inclusion of many elements would also allow the detection of variability between parts of the tooth row in their effect upon skull structure. This is a strong possibility as it is well established that different muscles generate different resultant vectors of force in the skull when different teeth are used in biting or chewing (Endo 1966).

A good attrition standard should also incorporate as many aspects of attrition as possible. For example, data on the extent of dentin exposure (Molnar 1971), interproximal wear (Wolpoff 1971), helicoidal wear (Butler 1969), as well as cupped versus rounded anterior tooth wear (Hinton 1981b) could be collected for every skull. Each of these may carry different information about dental function and the biomechanics of chewing. It is also clear that patterns of tooth wear differ between populations (see Brace and Molnar 1967:213 for references). Thus inclusion of many dental elements and scoring of different aspects of tooth wear have obvious advantages in this regard.

The consumate set of tooth wear variables should also have as many levels of attrition as possible so as to be sensitive to small shifts in the biomechanical effects of dental function over a large range of attritional severity. Finally, the tooth wear scoring method should make possible the computation of wear for each individual (see Chapter II).

These ideals were virtually impossible to achieve. To conduct truly independent statistical tests for each of these kinds of variables would require several hundreds of well preserved, undeformed adult skulls of each sex of each population with few or no missing teeth. Few if any archeological skeletal collections like this are available. This does not mean that small scale, cautious tests for the effects of tooth wear on cranial variation cannot be made if care is taken not to overinterpret the results.

So that compatibility could be achieved between sample sizes and the complexity of the statistial analyses several limitations were imposed on the technique of scoring tooth wear. It was decided to limit the dental attrition variables so as to assess only the extent of dentin exposure as viewed from the tooth's occlusal aspect. Four variables were recorded for each specimen:

ANT--wear of anterior teeth (incisors and canines).

M1--wear of first molars.

M2--wear of second molars.

M3--wear of third molars.

The variable, M3, was not used in any of the analyses because it was found that the populations studied showed little or no within-group variability in M3 score.

Figure 4 exhibits the standards used to score teeth for

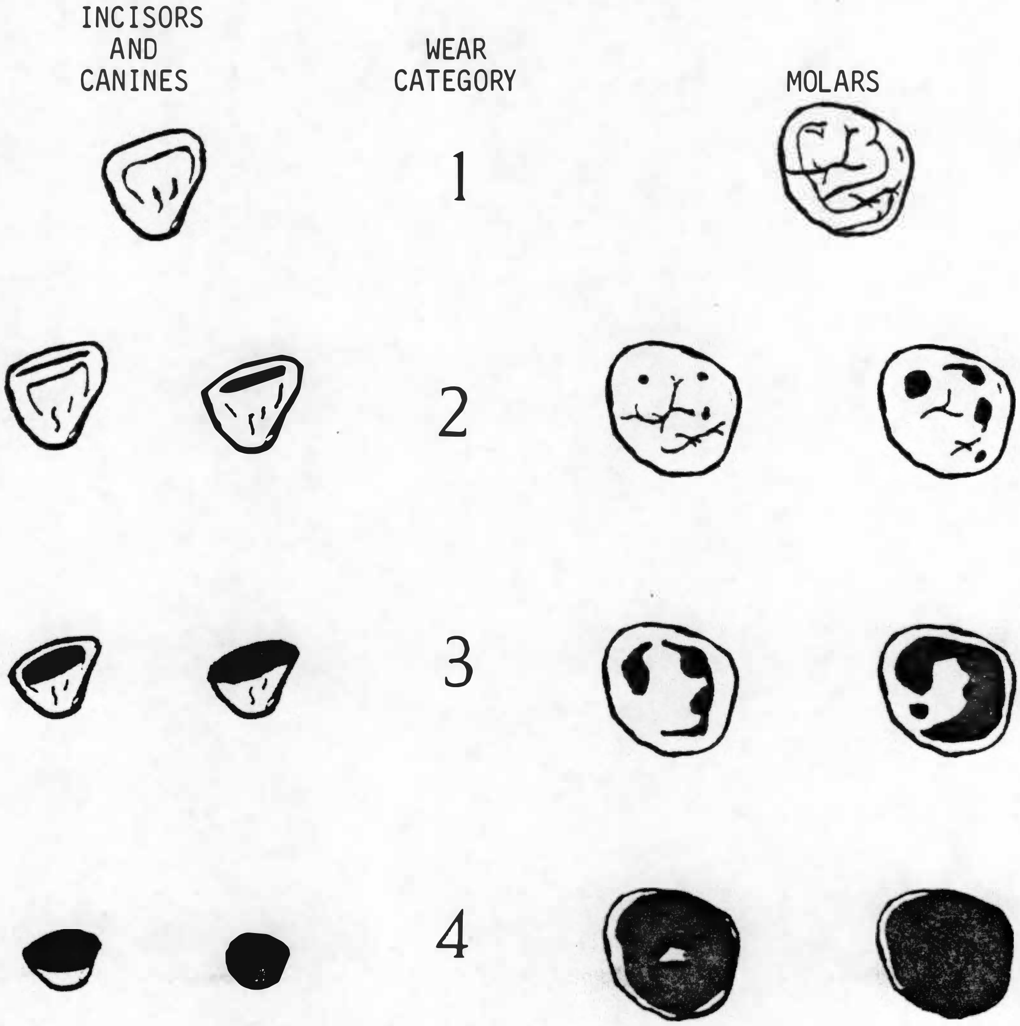


FIGURE 4. STANDARDS FOR SCORING DENTAL ATTRITION

severity of wear. These standards are a condensation of Hinton's (1979), which were, in turn, derived from Molnar (1968). The blackened areas indicate dentin exposure, and perhaps pulp cavity exposure in severe cases. Category 1 teeth may show some polishing of enamel at points of occlusion, but no exposure of dentin. Category 2 incisors and canines vary from a pinpoint or thin line of visible dentin to a stage where even a casual glance discloses the fact of dentin exposure. Category 2 molars exhibit one or more pinpoints of dentin, and these may show signs of enlargement. Classification of Category 3 anterior teeth is quite subjective, but becomes easy and replicable through experience. Dentin exposure is quite pronounced, but plenty of enamel is still present, and the crown as a whole cannot yet be described as a "nub." For molars of Category 3 the points of dentine exposure have begun to coalesce, and the sum of exposed dentin may take up the majority of occlusal area. Anterior teeth of Category 4 are little more than nubs with little and sometimes no enamel apparent. Category 4 molars have occlusal surfaces that are almost completely dentin material. They may exhibit a small island or peninsula or remaining enamel, or a thin strip of enamel on the buccal or lingual margins of the occlusal surface. Decayed or broken teeth were not scored if there was any question at all as to their correct category of wear.

In order to increase sample sizes it was necessary to pool several teeth into a single variable, using their average appearance to assess that variable's score. Thus ANT was the average score of all incisors and canines available from either arch and either side of the mouth. The molar variables are, likewise, the average score of the molars present--upper, lower, right, or left. Molnar (1971) reported that for a sample of California Indian skulls (dated circa 2000-2500 B.P.) there was bilateral variance in the extent of wear in all teeth. He also notes that upper teeth tend to be more worn than lower teeth. Neither of these trends was tested for statistical significance in his study. It appears from Molnar's figures that the only differences large enough to have implications for the present study are those between the upper and the lower anterior teeth of females. Still there is little concern here for the procedure of averaging data from the sides and arches because few discrepancies were noted between the averaged teeth in any of the five populations. For this reason there was little hesitance to use only one or two teeth to determine the score for any particular tooth wear variable.

Premolars were excluded from the analyses. If sample sizes permitted it, their inclusion might have provided more information. As things are, they would have either raised the interdependence of the statistical tests beyond reasonable tolerance, or rendered these tests invalid.

If there was any evidence of antemortem tooth loss (i.e. alveolar resorption) the teeth missing were recorded as such. As explained in Chapter II, the data for individuals with too many of certain teeth missing were not used in certain analyses because antemortem tooth loss introduces new and undesirable complications into the relationship between attrition and the vectors of bite force.

It was possible to rescore all of the Yauyos teeth (several hours later) and all of the Larson teeth (16 months later). A total of 419 observations were rescored. Three hundred and eighty observations were the same, 20 were one score higher, and 18 were one score lower for the second scoring session. Ninety percent were given the same score for both sessions, and this was compared to the ideal of 100 percent using the arcsine transformation test for the equality of two percentages (Sokal and Rohlf 1969:607-608). The two scoring sessions were found not to be significantly different (P = 0.3121). Scores that differed between the two sessions were rechecked before recording the final data.

The SAS PROC MEANS (Barr et al. 1979) was used to compute the descriptive statistics of the attrition data separately for each sex of each population. The results are presented in Tables A-1 through A-20 in the Appendix. There was only one Larson female where M1 was scored as Category 1, and only one Yauyos male where ANT was equal to 4. These two individuals were excluded from analyses involving those populations and those variables.

CHAPTER V

STATISTICAL PROCEDURES

A. OVERVIEW AND RATIONALE

The overall purpose of the statistical analyses is to determine if dental attrition can account for a significant amount of craniometric variation. In the present case the dental attrition data are of the ordinal scale type, while the craniometric variables are all interval scale (Hays 1973). Under these conditions the usual procedure is to calculate generalized D^2's or conduct multivariate analyses of variance (MANOVAs), whereby the ordinal scale variables (attrition) are the independent or classification variables, and the interval scale variables (craniometrics) are the dependent variables (Tatsuoka 1971). With this approach each independent variable in the statistical model is tested for its effect on the overall variation of the dependent variables. If an independent variable, say M1 attrition, is found to "explain" or account for a significant amount of overall variation of the dependent variables, in this case the 70 cranial measurements, then it is desirable to know which of the measurements are affected by M1 attrition. To determine this 70 univariate analyses of variance (ANOVAs) could be conducted, one for each craniometric variable, and each using M1 as the independent variable.

There is a major drawback with this approach, however. There is a considerable amount of intercorrelation between the 70 craniometric variables, and thus the results of their 70 ANOVAs cannot be interpreted independently from each other. To illustrate let us suppose that M1 has a significant overall effect on cranial variation of a given skeletal population. Further suppose that glabello-occipital length, maximum cranial breadth, and basion-bregma height are the only variables significantly affected by M1 wear according to the ANOVAs. The ANOVAs also suggest that they are affected in such a way as to increase as the M1 score increases. Can we conclude that there is a uniform increase in head size as M1 attrition increases? Howells (1973) reports that for his 17 skeletal populations the correlations between these three variables range from 0.24 to 0.34. Perhaps the changes in each of the three variables are independent responses to the aggregate forces of dental function. We cannot be sure because of the intercorrelations of the cranial measurements.

The classical solution to this dilemma is to factor analyze the dependent variables before testing for the effects of independent variables upon them (Kim and Mueller 1978:60). Each resulting factor is a linear combination of the original variables, but with the advantage that all factors are mathematically independent of each other. Thus if M1 wear was found to have a significant effect on a factor's variation, it is safe to assume that this association is independent of M1 wear's effect on the rest of the cranial factors.

The meaning of a particular factor can be inferred by examining the strengths of association of that factor with each of the original variables. Ideally, only a few variables load on (i.e. associate with) each factor, and that factor is usually assigned a name that reflects its primary association with these variables.

Returning to our hypothetical example, suppose that a factor analysis produces a "cranial circumference" factor whose heaviest loadings are positive associations with glabello-occipital length and maximum cranial breadth, and a "cranial height" factor whose heaviest loading is a positive one with basion-bregma height. If scores on both of these factor scales increase as M1 wear increases then we can conclude that the response of basion-bregma to M1 change is independent of the responses of head length and head breadth. Also, head length and breadth respond concomitantly to M1 variation. Such a conclusion would be more accurate and would certainly require a different developmental or biomechanical interpretation than a conclusion of overall head size increase.

The factor analysis approach has an additional advantage. The initial step of a factor analysis usually produces as many factors as there are variables, but generally only a small number of these factors are used in subsequent analyses. Factors are extracted from the correlation matrix in decreasing order of the amount of variation they account for in the raw data. The few factors that are kept for further scrutiny are those that are the first computed, and consequently account for a large proportion of the population's variation in the original measurements. Admittedly, some information is lost when one chooses to work with a small number of factors. In the realm of craniometrics, however, the trade-off of information for simplicity has been considered a worthwhile one. For example, in Howells' (1973) study of worldwide cranial variation he reduced 70 cranial measurements down to 18 factors which accounted for 73.6 percent of the total variation in his 17 skeletal samples. Likewise, Key and Jantz (1981) found that 14 factors adequately represented their 55 variables in a study of Arikara Indian craniometrics, although 22 percent of the original variation was lost in the bargain. Clearly it is much easier to comprehend the patterns of variability among less than a score of independent factors than among three times as many intercorrelated variables.

The general outline of the statistical procedures was as follows. The pooled within-groups correlation matrix for the craniometric variables was factored. Scores on the more important factors were then calculated for all skulls. These factor scores were then used as the dependent variables for MANOVAs, wherein sex and various attrition scores were the independent effects to be tested. MANOVAs were done separately for the five skeletal samples. If the dental attrition variable was found to have a significant overall effect on cranial factor structure, then separate ANOVAs were done--one for each cranial factor and using sex and the attrition variables as independent effects. This revealed, as far as was possible, what aspects of cranial morphology were affected by dental attrition. As a backup to the univariate ANOVAs, Spearman's correlation coefficients were computed between attrition scores and factor scores. Spearman's r is a better test of whether the heterogeneity in factor scores among wear levels is ordered. (The following sections explain in detail each step of the analyses.)

Because the factor approach sacrifices some craniometric information the question arises as to the effect of this loss on the

MANOVAs. Might the probability of attrition category differences be more accurately calculated if all available craniometric variation were used? A desirable procedure would be to first do the MANOVAs with all 70 cranial variables in order to get the best estimate of the significance of attrition category differences. The MANOVAs could then be redone with a smaller number of factors in order to get a better idea of how the categories differ morphologically. Unfortunately, the sample sizes of the 10 sex/sample groups are too small to do multivariate analyses with 70 dependent variables. Therefore, it is assumed here that the overall significance tests are reliable for the MANOVAs that use scores of a limited number of factors.

B. FACTOR ANALYSIS

The correlation matrix used in the factor analysis was a pooled within-groups matrix computed from the 10 sex/sample groups. This matrix was computed by the FORTRAN program, WITHIN, which is a modification by Stewart Hawkinson and Pat Key of Davie's (1971) discriminant function program. For each sex of each of the five samples the program computes a variance-covariance matrix for the 70 cranial variables. These 10 matrices are consecutively pooled into a single matrix in such a way that their contribution to the final matrix is weighted by their sample sizes. WITHIN then converts this variance-covariance matrix into the correlation matrix to be factored.

The within-groups correlation matrix, and the factors extracted from it, contain information about the patterns of variable intercorrelation that are common to all groups involved. For this reason the effects of dental function upon the factors must be interpreted in terms of the patterns of cranial factor structure that are shared by all groups used in the analysis. It would also be desirable to factor each of the 10 sex/sample correlation matrices and subsequently conduct MANOVAs to test for the effects of dental attrition on the factors. In this way the effects of attrition (or age) on the cranial variation within each group could be more precisely and accurately viewed. However, it is generally considered very poor practice to factor correlation matrices computed from fewer individuals than there are variables. Unfortunately, this is the situation for all of the sex/sample groups used herein, the largest sample size being 67 for the Larson females. The pooled within-groups correlation approach is satisfactory in this regard because the total number of skulls used is 515 as compared to 70 measurements and angles.

The within-groups matrix was used as input for the BMDP4M factor analysis program (Dixon et al, 1979; Frame and Hill 1974). The PCA option was specified, so the method of initial factor extraction was that of principal components analysis. However, it was specified that the squared multiple correlations (SMCs) of each variable with all others be used as diagonal elements in the correlation matrix. For this reason the kind of factor analysis actually executed was a principal factor analysis with no iterations (Harman 1976:135-141). This is one of the simplest and most straightforward of the factor analysis techniques in use today.

The program automatically computes and prints out the SMCs of all the variables. After the first run of BMDP4M these values were examined to see if all the variables should be used in the factor analysis. If the value of a variable's SMC is low, that variable's association with other variables as a whole can be considered to be weak. In other words the likelihood of that variable forming a factor in conjunction with others is low. Inclusion in a factor analysis of variables with inordinately low SMCs can be an unnecessary mathematical burden. (See Harman's (1976:84-90) discussion of the effect of low SMCs on the Grammian properties of the correlation matrix.)

Dr. John Philpot (personal communication) has proposed a useful criterion for variable exclusion. If a variable has an SMC that is over two standard deviations below the mean SMC for all variables then that variable should be excluded. This exclusion is only for the factor analysis. Subsequent analyses (e.g. MANOVA) which use the factor scores as input should also use raw data from the excluded variables as input. There should be no concern for the possibility of intercorrelations of the variables with the factors or with each other. Their independence will have been demonstrated by their low SMCs.

After the appropriate variables were excluded from the within-groups correlation matrix the BMDP4M program was run again. Four criteria were used to determine the number of factors to be kept for the subsequent MANOVAs. First, a "scree" test was done whereby factor eigenvalues were plotted against factor numbers (Harman 1976:163). A break in the plotted curve suggests that factors occurring before the break should be kept. The second criterion is a common one--that of keeping factors whose eigenvalues are greater than 1.0 (Kim and Mueller 1978:43). In addition, it was arbitrarily determined that enough factors should be kept to account for at least 70 percent of the total within-groups variance.

These three criteria allowed preliminary selection of the numbers of factors to be kept. At this point BMDP4M was again executed, but the number of factors to be kept was limited to the preliminary figure, and output of a "residual" correlation matrix was requested. This latter matrix represents the leftover correlations that are not accounted for by the factors kept. (See Dixon et al. (1979:647) for computational details.) Ideally, all of its off-diagonal elements should be nearly 0.0, a condition which indicates that all significant patterns of variable intercorrelation have probably been extracted from the matrix. Thus, the final criterion of selection of the number of factors to be kept was that nearly all the off diagonal elements of the residual correlation matrix be less than 0.0999.

The matrix of correlations between the variables and the factors is called the factor pattern matrix. Examination of the "loadings," or correlations, in this matrix suggests which variables a factor best represents (i.e. the morphological meaning of a factor). Frequently the pattern matrix of the factors kept after initial extraction is "rotated" mathematically in such a way as to increase the variability of the loadings for each factor. This increased variability means that for each factor fewer variables will have loadings with high absolute values. The craniometric meaning of the factors is thus easier to interpret, yet the aggregate information of all the kept factors is undiminished. The method of factor rotation used here was VARIMAX. This procedure has the advantage of preserving orthogonality between the factors as they are rotated to their final solution. Recall that achieving independence among factors was the major purpose of doing factor analysis. (See Kim (1975), or Kim and Mueller (1978) for a lucid discussion on factor pattern rotation and the VARIMAX method.)

Interpretation of factor patterns, even after rotation, can sometimes be a subjective process. Variables with loadings of higher absolute values on a factor are of interest, but there is sometimes no clear break between the higher and lower absolute values of loadings. The procedures used herein for interpretation of the rotated factor pattern are as follows. Each variable's highest absolute value correlation was marked. The lowest absolute value thus marked was considered the lowest salient loading of the entire matrix. Therefore, every loading in the matrix having an absolute value greater than this salient loading was marked. Some leeway was made so that values slightly less than the lowest salient loading were also marked. Each factor was interpreted to represent the variables whose loadings were marked in that factor's loading vector.

The FORTRAN program, ZSCORE, written by Key (Key and Jantz 1981), was used to calculate every individual's factor scores for all rotated factors. Input for ZSCORE consists of: (1) raw craniometric data; (2) grand means and within-groups standard deviations (output by the WITHIN program); and (3) the factor score coefficient matrix (output by BMDP4M). ZSCORE first calculates Z scores by centering the data on the grand means and dividing through by the within-groups standard deviations. The matrix of factor scores is produced via postmultiplication of the Z scores by the factor score coefficient matrix.

When all sex/sample groups are considered together the factor score means are zero and their standard deviations are 1.0.

C. MULTIVARIATE ANALYSES OF VARIANCE

The common multivariate procedures, discriminant analysis and Mahalanobis' D^2, can be considered as particular applications of the more general procedure of multivariate analysis of variance (MANOVA). The MANOVA's test of the effect of a discrete, independent variable (say sex) upon dependent variables is a computation of the "distance" between the means of the two sexes in multivariate space, and a test for significance of that distance. In the present study the ordinal scale variables of anterior tooth wear (ANT), first molar wear (M1), and second molar wear (M2) were treated as classification variables. The MANOVA test for the effect of ANT on cranial variation can thus be thought of as a test for significance of the craniometric distance between the discrete levels of anterior tooth wear.

The SAS procedure, GLM, was used to do the MANOVAs (Barr et al. 1979). MANOVAs were done separately for the five samples, and within each sample separate MANOVAs were done for ANT, M1, and M2. The dependent variables of each MANOVA computer run included all the factor scores of the population in question plus the population's data for the variables not included in the factor analysis. The independent variables were sex, the tooth wear variable, and sex-by-tooth wear interaction. The test for the effect of each of these three variables upon the dependent variables can be interpreted with the assurance that the effect of the other two independent variables has been taken into account. For example, if a run of the GLM procedure shows that M1 has a significant influence on the craniometric variation of the Berg, we know that this is the case even after sex differences and sex-M1 interactive effects are accounted for. If the test for M1's effect were computed without consideration of sex differences in skull structure we could not be certain that our M1 test result did not merely reflect the fact that one sex had more tooth attrition than the other.

It is important that the interaction of the main effects of sex and wear be included in the MANOVA model. Consider the hypothetical case where, for a given skeletal collection, it was found that there were no craniometric differences between the sexes (admittedly unlikely) and no differences between the categories of tooth wear. It still might be that males with higher attrition differed craniometrically from females with lower attrition. In other words, attrition could affect the skull structure of the two sexes in different ways, but this effect would be undetectable without an interaction term in the model. For this reason all MANOVAs initially included the sex-wear interaction term as an independent variable. For those runs where the interaction was found not to be significant the term was dropped and the model was run again, but only with tests for sex and tooth wear. This elimination of insignificant terms improves the degrees of freedom for the statistical tests.

The statistically informed reader may be concerned that all data for all five groups were not included in a single MANOVA which used the additional independent variables of "group" and its associated interaction terms. In this way it could have been determined with more confidence whether or not there is racial variation in the way that age/dental function affects cranial variation. Sample sizes, however, did not permit the inclusion of any more independent variables into a MANOVA design than those discussed above. An advantage of examining the groups separately is that it alleviates concern over the effects of population variability in the amount of grit ingestion upon tooth wear (Molnar 1972).

(See Morrison (1976:170, 193) or Tatsuoka (1971: 194, 216) for a thorough discussion of the points raised in the preceding sections.)

D. ANALYSES OF VARIANCE

While the MANOVA is an appropriate overall test for the influence of attrition on cranial variation, the analyses of variance (ANOVAs) may reveal the specific factors or variables influenced by attrition.

The GLM program was also used for the ANOVAs. For each MANOVA that revealed a significant tooth wear or interaction effect ANOVAs were conducted using the same data. For example, if the sex-M1 interaction was significant in the Berg then an ANOVA was done for each of the craniometric factors and variables using the Berg data. The independent effects were sex, M1, and sex-M1 interaction--the same model used for the Berg MANOVA, and for the same reasons.

E. SPEARMAN'S RANK ORDER CORRELATIONS

The data for interval scale variables such as cranial length can be objectively collected and the researcher can be assured that the length of a unit interval at one point on the scale (e.g. 161-162 mm) is the same length as any other unit interval on the scale (e.g. 172-173 mm). These features make interval scale data very powerful and sensitive when used as independent variables in MANOVAs or ANOVAs (Hays 1973:85-87). However, these assumptions cannot be met when teeth are objectively scored for amount of exposed dentine. (See Scott 1979 for an opposing view.)

In the present study it cannot be assumed that the difference between wear stages 1 and 2 is the same as between stages 3 and 4. The wear data are at best of ordinal scale (i.e. the stages 1 through 4 can be considered ranked from lowest to highest). Unfortunately, no satisfactory ANOVA or MANOVA techniques exist that can use more than one non-interval scale variable as independent variables. It was therefore necessary to treat the attrition variables as discrete trait variables in the MANOVAs and ANOVAs. This was an exceptionally conservative and insensitive procedure as no assumption was made about the ordering of the four categories of tooth wear. Therefore, it is far more likely that real tooth wear effects on craniometrics would be overlooked (Type II error) than that unreal cranial differences between wear categories would be reported by the ANOVAs (Type I error).

To increase the sensitivity of the attrition variables and lower the possibility of Type II error the following steps were taken with each skeletal collection that showed a noteworthy overall tooth wear effect in the MANOVA. First the SAS program, STANDARD (Barr et al. 1979), was used to convert each of the factor scores (and cranial variables that were never factored) into Z-scores, each of which had a mean of 0.0 and a variance of 1.0. This was done separately for each sex. The Z-scores for the two sexes were then combined into a single data set. For this data set Spearman's correlation coefficient, r_s, was computed between the tooth wear variable on the one hand and each of the factors and craniometric variables on the other. The r_s values were computed by the SAS program, CORR (Barr et al. 1979), which printed the level of significance for each value.

The rationale for standardizing the cranial factors and variables of each sex was to eliminate the influence of sex on cranial variation before testing for the effects of dental attrition. In other words the significance level of the r_s values could be interpreted without fear that they may actually represent sex differences in the degree of dental attrition. (See Sneath and Sokal (1973:154), and the multivariate analysis of variance section above, for elaboration.)

CHAPTER VI

RESULTS

A. FACTOR ANALYSIS[1]

The initial run of the BMDP4M program showed that the squared multiple correlations (SMCs) of the 70 variables had a mean of 0.8391 and a standard deviation of 0.2039. Three variables had an SMC over two standard deviations below the mean: mastoid height (0.3808), mastoid width (0.3654), and supraorbital projection (0.3228). These variables were not used in the final factor analysis, but their raw data were later reunited with the final factor scores and this total set was used as the dependent variables in the MANOVAs.

Selection of a particular number of factors for final VARIMAX rotation proved to be a subjective decision as is often the case. The "scree" plot of eigenvalues on factor numbers was not helpful as there were no clear breaks in the pattern. Seventeen factors had eigenvalues greater than unity. The sum of the eigenvalues of these 17 factors was 54.336. Dividing this figure by the number of variables factored, 67, indicates that 81.1098 percent of the within-population variation of the 67 variables can be accounted for by the

---

[1] A copy of the pooled within-groups correlation matrix of 70 craniometric variables may be obtained from the author upon request. A copy is also permanently on file at the Department of Anthropology, The University of Tennessee, Knoxville.

first 17 factors. The trace value of the 67 variable correlation matrix was 57.5791. Dividing the sum of the 17 eigenvalues by the trace value reveals that the first 17 factors account for 94.3671 percent of the common factor variance. This percentage as well as the percentage of variable variance explained are very satisfactory.

The first 17 factors were, therefore, rotated to their VARIMAX solution. An examination of the residual correlation matrix left after these factors were extracted showed that only five out of 2,211 off-diagonal elements had absolute values greater than 0.0999. This was final confirmation that 17 factors adequately represented the 67 variables.

The rotated factor pattern, i.e. the matrix of correlations between the variables and the rotated factors, is presented in Table A-11 of the Appendix. In order to facilitate factor interpretation only loadings with absolute values greater than 0.249 are given. In addition, the variable order has been rearranged by BMDP4M so that the more important variables of the more important factors are listed first. The lower salient loading in the factor pattern was found by the method given in the previous chapter to be 0.351. Therefore, values between 0.350 and -0.350 were not given much consideration in the factor interpretations.

Below, the factors are interpreted morphologically. It should be restated here that these factors are the factors of craniometric covariation that are common to all 10 of the sex-by-population groups analyzed. The frequent comparisons to Howells' study are in reference to his 1973 monograph, which should be consulted for measurement definitions. Where possible the factors are given the same name as those of Howells' (1973). Beneath the description of each factor are given the important loadings and variable code names.

1. Facial forwardness. This factor accounts for 13.651 percent of the total within-population variable variance. This was also Howells' most important factor. Most of the important loadings are on radii measured from the transmeatal axis to various parts of the face. The two measurements from basion to nasion and to prosthion also indicate that this factor represents overall facial forwardness. Glabello-occipital and naso-occipital lengths probably load here because they too measure, in part, the projection of the face anterior to mid-cranium.

EKR	.913	ZMR	.851	NAR	.793	BPL	.682
ZOR	.893	DKR	.812	PRR	.768	GOL	.476
FMR	.855	SSR	.810	BNL	.697	NOL	.462

2. Upper facial breadth. This was Howells' fifth factor, and it accounts for 8.336 percent of the variance here. It is composed exclusively of breadth measurements, five of which span the entire upper and upper-middle face. Left orbital and interorbital breadth load here, but nasal breadth does not. Three loadings, those of palate breadth, biauricular breadth and minimum cranial breadth (between the temporal fossae), demonstrate that this factor is not confined to the anterior, superior part of the face.

JUB	.800	FMB	.690	WCB	.624	DKB	.406
ZYB	.762	ZMB	.678	MAB	.563		
EKB	.730	AUB	.655	OBB	.486		

3. Orbital horizontal profile. The third factor accounts for 7.027 percent of the variance, and is comparable to Howells' seventh factor. This is clearly a factor of the forward projection of the interorbital area relative to the lateral orbit margins. Heavy loadings are from the subtenses from nasion and from left dacryon to the bifrontal breadth axis. Equally strong negative loadings come from the angles at nasion and left dacryon drawn to the frontomalare points. The variables with lower loadings, orbit breadth, and nasion and dacryon radii, also seem to be reflecting the degree of projection of the interorbital area as viewed in profile.

DKS	.884	NAS	.871	NAR	.415	OBB	.351
DKA	-.875	NFA	-.868	DKR	.397		

4. Occipital curvature and size. This is Howells' seventeenth factor, occipital curvature, combined with some of the information from his eighteenth and last factor, occipital size. Still it is easily interpreted, with major loadings from the occipital subtense to the lambda-opisthion chord (positive), and from the angle of the occipital in sagittal profile (negative). Figure 3 on page 35 illustrates this angle. Positive loadings from cranial length are probably reflecting the variation in the aforementioned subtense. The factor expresses more than shape. There are also positive loadings for lambda-opisthion length; and lambda-subtense fraction. A light positive loading from the profile angle of the parietals suggests that, as the occipital protrudes more posteriorly and enlarges, the parietal profile atop the head flattens somewhat. This factor accounts for 4.988 percent of the total within-population variable variance.

OCS .948 GOL .601 OCC .530 OCF .397

OCA .858 NOL .593 PAA .422

5. Facial height. This is Howells' fourth factor and it accounts for 4.794 percent of the variation. The highest loadings are positive ones for the angle formed by nasion and prosthion at basion, nasion-prosthion height, and nasal height. (This area is sometimes referred to as "upper facial height," as total facial height includes the mandible.) There are smaller positive loadings for cheek and orbit heights. The nasion angle to basion and prosthion loads negatively. It would be expected to decrease as facial height increases independently of changes in the rest of the skull.

BAA .915 NLH .773 NAA -.450

NPH .847 WMH .482 OBH .420

6. Interorbital prominence. This is not to be confused with the orbit horizontal profile factor or interorbital breadth (below). It is a combination of Howells' eighth and ninth factors and accounts for 4.434 percent of the variation here. This factor very clearly expresses the degree of forward projection of the mid-sagittal parts of the upper nasal bones relative to the medial parts of the orbits. Naso-dacryal subtense and simotic subtense load positively, and naso-dacryal angle and simotic angle load negatively.

NDA -.853 NDS .831 SIS .759 SIA -.684

7. Parietal size and profile. The variables of this factor are confined to the midsagittal plane. Bregma-lambda chord and the greatest subtense to this chord have high positive loadings. However, the angle formed from bregma and lambda to the point of subtense

measurement, i.e. the parietal angle, has a negative loading. Thus as the particles lengthen they become more bulbous in profile. Positive loadings from bregma subtense fraction and vertex radius simply reflect this trend. This is Howells' sixteenth factor. Here it accounts for 4.427 percent of the within-population variation.

PAS	.879	PAF	.664	VRR	.384
PAC	.838	PAA	-.658		

8. Vault breadth. This factor is similar, though not identical to Howells' third factor of the same name. All significant loadings are positive and the strongest are with maximum cranial, maximal frontal and bistephanic breadths. The other loadings of interest are from bistephanic and biauricular breadths. Vertex radius has a lower but noteworthy loading. This probably indicates that vault breadth is not totally independent of vault height. In this vein it is interesting that glabello-occipital and naso-occipital lengths have loadings of less than 0.10 on this factor. This establishes that vault breadth is independent of length. This factor accounts for 4.346 percent of the variable variance.

XCB	.779	STB	.699	AUB	.462
XFB	.714	ASB	.494	VRR	.430

9. Prognathism. This factor is equivalent to Howells' seventh, and it accounts for 4.018 percent of the variation. The heaviest loading is a negative one from the angle formed at prosthion by the nasion-prosthion and basion-prosthion lines. There is a concomitant positive loading from the angle formed at nasion by the basion-nasion and prosthion-nasion lines. These angles are illustrated in Figure 1

on page 33. Other notable loadings are positive ones from basion-prosthion length and the distance from prosthion to the transmeatal axis. Clearly this factor represents the variation in anterio-posterior location of prosthion relative to basion and nasion. It is not a measure of alveolar prognathism in relation to the malar bones.

PRA -.850	NAA .774	BPL .515	PRR .407

10. Frontal profile flatness. This is comparable to Howells' fifteenth factor and it accounts for 3.87 percent of the within-group variance. The factor primarily represents the amount of bossing of the frontal bone as viewed in profile. The heaviest loadings are a positive one with the maximum subtense to the nation-bregma chord, and a negative one with the angle formed at the point of subtense measurement by lines from nasion and from bregma. These are illustrated in Figure 3 on page 35. This factor also measures the overall size of the frontal bone. There are noteworthy positive loadings from the bregma-lambda chord, from bistephanic breadth, and from the nasion-to-basion-to-bregma angle. Thus skulls with more angled (bossed) frontal squama tend to have larger frontal bones.

FRS .907	FRC .440	BBA .382
FRA -.883	STB .387	

11. Vault height. This easily interpreted factor is apparently distinct from any of Howells' factors. Among the Larson Arikara and among the Murray River Valley Australians Key (1979) found similar (though not as easily interpretable) factors to which he gave the same name. Additionally, among several large series of Arikara crania Key and Jantz (1981) found separate anterior and posterior vault height

factors, but their combination would not quite be equivalent to this factor. There are positive loadings for basion-bregma height, the bregma-nasion-basion angle, lambda-opisthion chord, and vertex radius--all measures of vault height. A moderate negative loading occurs on the nasion-basion-bregma angle (illustrated in Figure 2 on page 34). A decrease in this angle might be expected to accompany vault height increases that occurred independently of vault length. The occipital angle has a positive but low loading with this factor (0.258). Therefore, the vault height factor may measure middle and anterior vault height more than posterior height. The factor accounts for 3.851 percent of the variance within the groups studied.

BBH	.789	OCC	.621	BBA	-.431
NBA	.627	VRR	.584		

12. Subnasal flatness. This factor, also Howells' twelfth, accounts for 3.461 percent of the variance. It is distinct from the prognathism factor described above. There are nearly equally heavy loadings with two variables: the subtense from subspinale to the chord connecting and right and left zygomaxillare anterior points (positive), and the angle at subspinale formed from the two zygomaxillare anterior points (negative). The factor is a simple but clear measure of the degree of anterior projection of the subnasal area relative to the malars. There is a lower positive loading with the radius from subspinale to the transmeatal axis that reflects this situation.

SSS	.865	SSA	-.864	SSR	.366

13. Frontal bone length. This factor measures the mid-sagittal

length of the frontal bone, and the anterior projection of glabella to a lesser extent. There are positive loadings with nasion-subtense fraction, nasion-bregma chord, nasion-basion-bregma angle, and glabellar projection. A moderate negative loading from the basion-nasion-bregma angle simply mirrors the covariation of the variables involved in this factor. Frontal bone length was Howells' fourteenth factor. Here it explains 3.272 percent of the total variation.

FRF	.743	BBA	.585	NBA	-.388
FRC	.642	GLS	.467		

14. Malar size. This simple factor was Howells' thirteenth. Inferior medio-lateral malar length, maximum malar length, and the maximum anterio-lateral projection of the malar all load positively. The factor accounts for 3.249 percent of the total within-population variation.

IML	.830	XML	.775	MLS	.630

15. Interorbital breadth. This name is not totally satisfactory because the interorbital breadth variable has the second highest loading, a positive one. The highest loading (positive) is with the simotic chord--the minimum horizontal distance across the nasal bones measured from the naso-maxillary sutures. This is the reverse loading order from Howells' tenth factor of the same name. Perhaps the present situation is a statistical artifact. This is one of the last factors and it only accounts for 2.799 percent of the variance. As higher numbers of orthogonal factors are introduced into the multivariate "factor space" it becomes increasingly difficult to accurately detect clusters of metric intercorrelations. The possibility remains that

this factor is morphologically accurate and that it should measure nasal bone breadth more than interorbital breadth. Simotic angle has a notable positive loading, but simotic subtense has a very low loading (0.159). The factor is therefore independent of the anterior prominence of the interorbital area, Factor 6. The positive loading from nasal breadth probably mirrors the general pattern of covariation in the interorbital region.

WNB .821 DKB .540 SIA .476 NLB .379

16. Foramen magnum length. A curious factor, this accounts for 2.373 percent of the total within-population variable variance. Howells found no such factor. The major loading is from the variable of the same name, with minor loadings, also positive from glabello-occipital and naso-occipital lengths. Key and Jantz (1981) used a variable not employed here, foramen magnum breadth, which combined with the length variable to give them a foramen magnum size factor. Perhaps foramen size does indeed vary independently from the rest of the skull.

FOL .777 GOL .383 NOL .377

17. Orbit size. This last factor is also distinct from any of Howells'. It accounts for only 2.201 percent of the within-group variance but it is easily interpreted and, therefore, probably real. Orbit height and breadth load positively, while cheek height loads negatively. This could mean that orbit size increases at the expense of cheek bone material, or that increases in cheek height encroach upon orbit space.

OBH .620 OBB .523 WMH -.453

B. MULTIVARIATE ANALYSES OF VARIANCE

During data collection and preparation it became apparent that there were some very small sample sizes for certain levels of tooth wear in certain of the groups studied. In addition, great imbalances were found in sample sizes within and between wear levels, wear variables and populations. These problems are illustrated in Table 2 which shows the sample sizes for each level of tooth wear for each tooth wear variable of each population.

I have been assured by the SAS Institute (personal correspondence from Alice Ray, Senior Statistical Editor) that the SAS GLM procedure is capable of doing multivariate analyses of variance (MANOVAs) with this kind of imbalanced data, and that analyses so conducted are statistically acceptable. However, from a morphological perspective there must be limits to the severity of imbalance that can be tolerated for a study such as this. For instance, it would not be very informative to compare one Berg male skull with level 1 anterior attrition to 33 Berg male skulls with level 2 anterior attrition. Therefore, after a subjective assessment of the situation it was decided that only the following groups of skulls would be analyzed via MANOVAs:

1. Berg for M1 levels 1 through 4
2. Berg for M2 levels 1 and 2
3. Tolai for ANT levels 2 and 3
4. Tolai for M1 levels 1 through 4
5. Tolai for M2 levels 1 through 3
6. Yauyos for M1 levels 1 through 3
7. Yauyos for M2 levels 1 and 2

TABLE 2. CONTINGENCY TABLES SHOWING IMBALANCE BETWEEN LEVELS OF TOOTH WEAR (SEXES COMBINED)[a]

WEAR LEVEL	ANT	M1	M2	ANT	M1	M2	ANT	M1	M2
		BERG			TOLAI			YAUYOS	
1	1	8	26	0	10	35	2	3	33
2	33	47	45	65	62	57	8	38	15
3	6	21	2	29	26	13	0	15	0
4	0	10	2	1	8	3	2	6	0
		SULLY			LARSON				
1	0	0	10	0	1	31			
2	12	8	34	34	35	48			
3	24	26	15	42	45	31			
4	32	33	7	40	37	9			

[a] Vertical lines correspond to the MANOVAs.

8. Sully for ANT levels 2 through 4
9. Sully for M1 levels 2 through 4
10. Sully for M2 levels 1 through 3
11. Larson for ANT levels 2 through 4
12. Larson for M1 levels 2 through 4
13. Larson for M2 levels 1 through 4.

These 13 groupings are marked by vertical lines in Table 2. None of the sex-tooth wear interaction terms were significant in any of the analyses. Consequently these terms were dropped from the models and the GLM procedure was again run but with tests only for the effects of sex and tooth wear.

The results are presented in Table 3. Not surprisingly, the sex effect is highly significant in every case. While in other contexts

TABLE 3. MANOVA TESTS FOR TOOTH WEAR AND SEX EFFECTS ON CRANIOMETRICS

GROUP/WEAR VARIABLE	WEAR LEVELS	EFFECT	F	(DF)	PROB
BERG M1	1,2,3,4	SEX	7.97	(20,54)	0.0001
		WEAR	0.92	(20,161)	0.6295
BERG M2	1,2	SEX	7.80	(20,46)	0.0001
		WEAR	1.44	(20,46)	0.1517[a]
TOLAI ANT	2,3	SEX	9.82	(20,72)	0.0001
		WEAR	0.66	(20,72)	0.8500
TOLAI M1	1,2,3,4	SEX	11.43	(20,82)	0.0001
		WEAR	1.04	(60,245)	0.4157
TOLAI M2	1,2,3	SEX	10.41	(20,81)	0.0001
		WEAR	1.43	(40,162)	0.0621[a]
YAUYOS M1	2,3	SEX	5.47	(20,30)	0.0001
		WEAR	0.85	(20,30)	0.6391
YAUYOS M2	1,2	SEX	3.80	(20,25)	0.0001
		WEAR	1.37	(20,25)	0.2240
SULLY ANT	2,3,4	SEX	7.33	(20,37)	0.0001
		WEAR	1.39	(40,74)	0.1099[a]
SULLY M1	2,3,4	SEX	6.12	(20,36)	0.0001
		WEAR	1.72	(40,72)	0.0231[a]
SULLY M2	1,2,3	SEX	7.83	(20,32)	0.0001
		WEAR	1.55	(40,64)	0.0593[a]
LARSON ANT	2,3,4	SEX	12.10	(20,71)	0.0001
		WEAR	1.28	(40,142)	0.1488[a]
LARSON M1	2,3,4	SEX	12.91	(20,70)	0.0001
		WEAR	1.79	(40,140)	0.0071[a]
LARSON M2	1,2,3,4	SEX	11.41	(20,72)	0.0001
		WEAR	0.89	(60,215)	0.6971

[a] Considered significant enough to warrant further scrutiny.

these may be of interest in themselves they will be ignored for the remainder of this report. For Sully and Larson, first molar wear clearly has a significant effect on cranial morphology, and further scrutiny via ANOVAs is in order. In spite of the fact that they were not significant at the 0.05 probability level, the following analyses deserve further consideration: Berg M2, Tolai M2, Sully ANT, Sully M2, and Larson ANT. The reasoning is as follows. The MANOVAs of Table 3 make no assumption about the ordering of the various levels of dental attrition scores, i.e. it is not assumed that level 3 is less severe than 4 but more severe than 2. Recall from the previous chapter that this was the problem with ANOVA as compared to Spearman's r. This is a conservative situation and the MANOVAs are thus somewhat insensitive to craniometric changes that occur along the line of increasing tooth wear. Also recall the conservative criteria of case exclusion based on antemortem tooth loss. These facts make it much more likely that real dental attrition effects would be missed in Table 3 than that spurious effects would be reported as statistically significant.

C. ANALYSES OF VARIANCE

For each ANOVA model the sex effect was entered into the analysis first. The GLM procedure could then correct for the effect of sex upon the cranial factor's variance before testing for a tooth wear effect. Each ANOVA table is followed by a table of factor score or craniometric variable means. The latter table indicates how the factor or measurement varies with changing tooth wear.

Only ANOVAs for which the tooth wear effect was statistically significant, or nearly so, and which complement the footnoted MANOVAs of Table 3 are presented below. Table 4 shows the noteworthy ANOVAs for Berg second molar attrition, and Table 5 presents the pertinent factor scores. These tables give clear indication that, at least during the earlier stages of wear, facial forwardness, facial height and interorbital prominence all increase as second molar wear increases.

TABLE 4. BERG M2 ANOVAS SHOWING NOTEWORTHY TOOTH WEAR EFFECTS

FACTOR (NO.)	SOURCE	DF	TYPE I SS	F	PROB
FACIAL FORWARDNESS (1)	SEX	1	10.4417	10.23	0.0021
	M2	1	7.3962	7.25	0.0090
	ERROR	65	66.3370		
FACIAL HEIGHT (5)	SEX	1	6.5250	5.76	0.0271
	M2	1	4.0598	3.58	0.0629
	ERROR	65	73.6672		
INTERORBITAL PROMINENCE (6)	SEX	1	4.8875	4.74	0.0331
	M2	1	5.8363	5.66	0.0203
	ERROR	65	67.0553		

The significant Tolai M2 ANOVAs and the corresponding means are given in Tables 6 and 7, respectively. For this Mealnesian sample the adult occipital becomes more curved and larger, and the frontal bone and mastoid lengthens as second molar wear progresses.

Table 8 presents the noteworthy ANOVAs for Sully Anterior attrition, and the corresponding cranial factor or variable means can be found in Table 9. From these tables it can be seen that as anterior

TABLE 5. FACTOR SCORE MEANS TO ACCOMPANY ANOVAS OF TABLE 4

M2 LEVEL	FACIAL FORWARDNESS (1)	FACIAL HEIGHT (5)	INTERORBITAL PROMINENCE (6)
1	-1.1635	-0.3531	0.1539
2	-0.4303	0.1929	0.7938

TABLE 6. TOLAI M2 ANOVAS SHOWING NOTEWORTHY TOOTH WEAR EFFECTS

FACTOR (NO.)	SOURCE	DF	TYPE I SS	F	PROB
OCCIPITAL CURVATURE AND SIZE (4)	SEX	1	5.7687	10.27	0.0018
	M2	2	6.4512	5.74	0.0044
	ERROR	100	56.1810		
FRONTAL BONE LENGTH (13)	SEX	1	34.6197	48.81	0.0001
	M2	2	5.8856	4.15	0.0186
	ERROR	100	70.9291		
MASTOID LENGTH	SEX	1	166.8687	18.52	0.0001
	M2	2	113.7902	6.31	0.0026
	ERROR	100	901.1776		

TABLE 7. FACTOR SCORE OR VARIABLE MEANS TO ACCOMPANY ANOVAS OF TABLE 6

M2 LEVEL	OCCIPITAL CURVATURE AND SIZE (4)	FRONTAL BONE LENGTH (13)	MASTOID LENGTH
1	-0.0467	-0.4756	26.5429
2	0.4709	0.0443	27.2857
3	0.7307	0.3603	29.8462

TABLE 8. SULLY ANT ANOVAS SHOWING NOTEWORTHY TOOTH WEAR EFFECTS

FACTOR (NO.)	SOURCE	DF	TYPE I SS	F	PROB
PARIETAL SIZE AND PROFILE (7)	SEX	1	3.1564	5.30	0.0250
	ANT	2	3.6299	3.05	0.0553
	ERROR	56	33.3322		
INTERORBITAL BREADTH (15)	SEX	1	0.7597	0.75	0.3916
	ANT	2	7.8177	3.84	0.0275
	ERROR	56	57.0632		
ORBIT SIZE (17)	SEX	1	5.7442	6.66	0.0125
	ANT	2	6.5676	3.81	0.0282
	ERROR	56	60.6258		
SUPRAORBITAL	SEX	1	39.1112	37.12	0.0001
	ANT	2	5.8213	2.76	0.0717
	ERROR	56	59.0003		

TABLE 9. FACTOR SCORE OR VARIABLE MEANS TO ACCOMPANY ANOVAS OF TABLE 8

ANT LEVEL	PARIETAL SIZE AND PROFILE (7)	INTERORBITAL BREADTH (15)	ORBIT SIZE (17)	SUPRAORBITAL PROJECTION
2	-0.7275	-0.5393	-0.1112	5.0833
3	-0.7109	-0.4066	-0.0583	5.4348
4	-0.1855	0.2407	0.5145	6.0800

wear progresses the parietal profile becomes larger and more angled in the midsagittal plane, and interorbital breadth, orbit size and supraorbital projection all increase.

Tables 10 and 11 show that interorbital breadth and orbit size also increase with increasing first molar attrition among Sully crania. Also, as M1 increases so does mastoid width. The profile of the frontal bone in the midsagittal plane becomes more angled from the first to the second M1 level, but the trend reverses dramatically between the second and third levels.

Tables 12 and 13 present the Sully M2 analyses and their means. The results are the same as those for first molar wear, except that the frontal profile becomes progressively flatter, with no reversals in the direction of change.

The noteworthy Larson ANT ANOVAs and factor score means are shown in Tables 14 and 15, respectively. As the front teeth wear down facial height and interorbital breadth increase, and the profile of the frontal bone flattens. The length of the foramen magnum is highest for the third (middle) level of ANT, and lower for the second and fourth levels.

Results for the Larson first molar analyses are found in Tables 16 and 17. As wear progresses facial forwardness increases and frontal bone length decreases. Occipital curvature and size has its highest mean in the third M1 level of war. This means that the occipital is most curved and largest in the midsagittal plane for the middle wear level, but smaller and flatter for the higher and lower wear levels. Table 17 shows that the midsagittal profile follows this same trend.

TABLE 10. SULLY M1 ANOVAS SHOWING NOTEWORTHY TOOTH WEAR EFFECTS

FACTOR (NO.)	SOURCE	DF	TYPE I SS	F	PROB
FRONTAL PROFILE FLATNESS (10)	SEX	1	16.5122	14.61	0.0003
	M1	2	6.3616	2.81	0.0686
	ERROR	55	62.1615		
INTERORBITAL BREADTH (15)	SEX	1	1.2752	1.34	0.2521
	M1	2	8.4904	4.46	0.0160
	ERROR	55	52.3648		
ORBIT SIZE (17)	SEX	1	4.4986	5.45	0.0233
	M1	2	4.9758	3.01	0.0574
	ERROR	55	45.4250		
MASTOID WIDTH	SEX	1	47.9508	21.07	0.0001
	M1	2	21.2132	4.66	0.0135
	ERROR	55	125.1411		

TABLE 11. FACTOR SCORE OR VARIABLE MEANS TO ACCOMPANY ANOVAS OF TABLE 10

M1 LEVEL	FRONTAL PROFILE FLATNESS (10)	INTERORBITAL BREADTH (15)	ORBIT SIZE (17)	MASTOID WIDTH
2	0.1493	-0.6990	-0.2630	11.1250
3	0.4608	-0.4039	0.0599	11.5206
4	-1.1695	0.1323	0.3192	13.1154

TABLE 12. SULLY M2 ANOVAS SHOWING NOTEWORTHY TOOTH WEAR EFFECTS

FACTOR (NO.)	SOURCE	DF	TYPE I SS	F	PROB
FRONTAL PROFILE FLATNESS (10	SEX	1	14.1536	12.44	0.0009
	M2	2	9.8130	4.31	0.0186
	ERROR	51	58.0087		
INTERORBITAL BREADTH (15)	SEX	1	1.0195	0.98	0.3265
	M2	2	6.5139	3.14	0.0519
	ERROR	51	52.9651		
ORBIT SIZE (17)	SEX	1	5.4124	6.63	0.0130
	M2	2	6.8281	4.18	0.0208
	ERROR	51	41.6273		
MASTOID WIDTH	SEX	1	40.3525	16.91	0.0001
	M2	2	22.1560	4.64	0.0140
	ERROR	51	121.6733		

TABLE 13. FACTOR SCORE OR VARIABLE MEANS TO ACCOMPANY ANOVAS OF TABLE 12

M2 LEVEL	FRONTAL PROFILE FLATNESS (10)	INTERORBITAL BREADTH (15)	ORBIT SIZE (17)	MASTOID WIDTH
1	0.1858	-0.8659	-0.4003	11.6000
2	-0.7492	-0.1616	0.0873	11.9091
3	-1.3338	0.1225	0.5945	13.4167

TABLE 14. LARSON ANT ANOVAS SHOWING NOTEWORTHY TOOTH WEAR EFFECTS

FACTOR (NO.)	SOURCE	DF	TYPE I SS	F	PROB
FACIAL HEIGHT (5)	SEX	1	6.1934	6.48	0.0126
	ANT	2	6.1834	3.24	0.0440
	ERROR	90	86.0129		
FRONTAL PROFILE FLATNESS (10)	SEX	1	10.3798	14.78	0.0002
	ANT	2	3.7709	2.68	0.0737
	ERROR	90	63.2209		
INTERORBITAL BREADTH (15)	SEX	1	0.0002	0.00	0.9862
	ANT	2	4.5245	3.62	0.0306
	ERROR	90	56.1719		
FORAMEN MAGNUM LENGTH (16)	SEX	1	7.6917	9.82	0.0023
	ANT	2	4.5358	2.90	0.0605
	ERROR	90	70.4981		

TABLE 15. FACTOR SCORE MEANS TO ACCOMPANY ANOVAS OF TABLE 14

ANT LEVEL	FACIAL HEIGHT (5)	FRONTAL PROFILE FLATNESS (10)	INTERORBITAL BREADTH (15)	FORAMEN MAGNUM LENGTH (16)
2	0.5007	0.2752	-0.4522	-0.2851
3	0.9877	-0.1617	-0.0430	-0.0056
4	1.2885	-0.4043	0.0550	-0.5956

TABLE 16. LARSON M1 ANOVAS SHOWING NOTEWORTHY TOOTH WEAR EFFECTS

FACTOR (NO.)	SOURCE	DF	TYPE I SS	F	PROB
FACIAL FORWARDNESS (1)	SEX	1	16.4530	19.21	0.0001
	M1	2	4.6104	2.69	0.0733
	ERROR	89	76.2439		
OCCIPITAL CURVATURE AND SIZE (4)	SEX	1	6.5069	8.51	0.0045
	M1	2	5.2428	3.43	0.0368
	ERROR	89	68.0656		
PARIETAL SIZE AND PROFILE (7)	SEX	1	5.4616	5.86	0.0175
	M1	2	5.8683	3.15	0.0477
	ERROR	89	82.9174		
FRONTAL BONE LENGTH (13)	SEX	1	25.0209	21.50	0.0001
	M1	2	6.6482	2.86	0.0628
	ERROR	89	103.3579		
INTERORBITAL BREADTH (15)	SEX	1	0.0376	0.06	0.8068
	M1	2	5.0554	4.04	0.0210
	ERROR	89	55.7118		

TABLE 17. FACTOR SCORE MEANS TO ACCOMPANY ANOVAS OF TABLE 16

MI LEVEL	FACIAL FORWARDNESS (1)	OCCIPITAL CURVATURE AND SIZE (4)	PARIETAL SIZE AND PROFILE (7)	FRONTAL BONE LENGTH (13)	INTERORBITAL BREADTH (15)
2	0.0376	-0.5209	-0.5189	0.0295	-0.4182
3	0.5538	-0.0517	-0.2109	0.2412	0.0598
4	0.9094	-0.5595	-0.7684	-0.1811	-0.0013

Finally, interorbital breadth also has its highest value for the third level of M1 wear. The differences between the mean interorbital breadth of the third and fourth level groups is not very great. It could be that interorbital breadth continually increases through adulthood for this sample and tooth wear variable, but the results reported in Table 17 are due to sampling error. The Spearman's correlation analyses below may clarify things.

D. SPEARMAN'S RANK ORDER CORRELATIONS

As with the ANOVAs, only the statistically significant or nearly significant Spearman's correlation coefficients are reported below. The results of the Berg M2 analyses, shown in Table 18, are identical to those from the ANOVAs of Tables 4 and 5, pages 71 and 72. The significant Spearman's correlations for the Tolai M2 variable are reported in Table 19. Occipital curvature and size, frontal bone length, and mastoid length were found to increase with increasing second molar wear. These results are the same as those for the corresponding ANOVAs. However, Table 19 reports two new noteworthy trends: orbit size and supraorbital projection are positively correlated with M2 attrition.

Table 20 presents the results for the Sully ANT wear variable. Here again, as in the ANOVAs, it is shown that factor scores for parietal size and profile, interorbital breadth, orbit size and supraorbital projection all increase as dental attrition increases. But the Spearman's analyses reveal several new trends. As tooth wear becomes more severe facial forwardness increases, while foramen magnum length

TABLE 18. NOTEWORTHY SPEARMAN'S CORRELATIONS FOR THE BERG M2 VARIABLE

FACTOR (NO.)	SPEARMAN'S R	PROB
FACTOR FORWARDNESS (1)	0.3304	0.0067
FACIAL HEIGHT (5)	0.2702	0.0282
INTERORBITAL PROMINENCE (6)	0.2897	0.0183

TABLE 19. NOTEWORTHY SPEARMAN'S CORRELATIONS FOR THE TOTAL M2 VARIABLE

FACTOR (NO.)	SPEARMAN'S R	PROB
OCCIPITAL CURVATURE AND SIZE (4)	0.3211	0.0009
FRONTAL BONE LENGTH (13)	0.2382	0.0149
ORBIT SIZE (17)	0.2282	0.0198
MASTOID LENGTH	0.2526	0.0097
SUPRAORBITAL PROJECTION	0.1866	0.0578

decreases. In addition, the frontal bone flattens in the midsagittal plane and the subnasal area becomes less projecting relative to the malars.

The Sully M1 correlations are found in Table 21. Three factors gave the same results as for the ANOVAs. As first molar wear increases interorbital breadth, orbit size and mastoid width all increase. According to the Spearman's value for frontal profile flatness the frontal bone continually flattens as Sully first molar wear progresses.

TABLE 20. NOTEWORTHY SPEARMAN'S CORRELATIONS FOR THE SULLY ANT VARIABLE

FACTOR (NO.)	SPEARMAN'S R	PROB
FACIAL FORWARDNESS (1)	0.2614	0.0436
PARIETAL SIZE AND PROFILE (7)	0.2734	0.0345
FRONTAL PROFILE FLATNESS (10)	-0.2902	0.0245
SUBNASAL FLATNESS (12)	-0.2708	0.0364
INTERORBITAL BREADTH (15)	0.3026	0.0188
FORAMEN MAGNUM LENGTH (16)	-0.2345	0.0714
ORBIT SIZE (17)	0.3276	0.0106
SUPRAORBITAL PROJECTION	0.2883	0.0255

TABLE 21. NOTEWORTHY SPEARMAN'S CORRELATIONS FOR THE SULLY M1 VARIABLE

FACTOR (NO.)	SPEARMAN'S R	PROB
FRONTAL PROFILE FLATNESS (10)	-0.3009	0.0206
SUBNASAL FLATNESS (12)	-0.2548	0.0515
INTERORBITAL BREADTH (15)	0.3316	0.0103
ORBIT SIZE (17)	0.2744	0.0355
MASTOID WIDTH	0.3009	0.0206

This indication is contrary to the trend in factor means found in Table 11, page 75, where it was shown that the middle level of M1 wear had the highest mean. This conflict probably indicates that the mean factor score differences between M1 levels 2 and 3 are insignificant. Thus it is concluded that the Spearman's r is not misleading us very much--frontal profile flatness does not change early in adulthood, but does become flatter in older age.

Returning to Table 21 we see that the subnasal area becomes less projecting with higher levels of wear. The corresponding ANOVA was insensitive to this trend.

Table 22 reports six notable Spearman's correlations from the Sully M2 analyses. The increases in facial forwardness, interorbital breadth and orbit size, and the flattening of the frontal profile all agree with the other two Spearman's analyses for Sully (Tables 20 and 21). The increase in mastoid width also reflects the same finding in Table 21 for Sully first molar wear. The change in facial forwardness is a trend that the Sully M2 ANOVAS (Table 12, page 76) failed to detect.

TABLE 22. NOTEWORTHY SPEARMAN'S CORRELATIONS FOR THE SULLY M2 VARIABLE

FACTOR (NO.)	SPEARMAN'S R	PROB
FACIAL FORWARDNESS (1)	0.3147	0.0193
FRONTAL PROFILE FLATNESS (10)	-0.4138	0.0017
INTERORBITAL BREADTH (15)	0.3021	0.0250
ORBIT SIZE (17)	0.3380	0.0116
MASTOID WIDTH	0.2919	0.0306

The Spearman's r values for the Larson ANT variable are presented in Table 23. As with the ANOVAs it is seen that facial height and interorbital breadth increase, and the frontal bone flattens in profile as the anterior teeth become more worn. As with the Sully M1 variable, subnasal flatness is shown to be negatively correlated with anterior tooth wear--a trend missed by the ANOVAs. Recall that Table 15, page 77, demonstrated that foramen magnum length was greatest for the middle level of Larson ANT and lower for the higher and lower tooth wear levels. This interpretation will be accepted, as no unidirectional relationship was found between these two variables by Spearman's r.

TABLE 23. NOTEWORTHY SPEARMAN'S CORRELATIONS FOR THE LARSON ANT VARIABLE

FACTOR (NO.)	SPEARMAN'S R	PROB
FACIAL HEIGHT (5)	0.2660	0.0096
FRONTAL PROFILE FLATNESS (10)	-0.2224	0.0312
SUBNASAL FLATNESS (12)	-0.2295	0.0261
INTERORBITAL BREADTH (15)	0.2287	0.0266

The Spearman's values of Table 24 show fewer significant relationships between Larson M1 and the cranial factors than did the ANOVAs (Tables 16 and 17, page 78). The Spearman's r suggests that frontal bone length continually decreases as wear increases. However, this negative correlation is not significant at the 0.05 level of confidence (P = 0.0778). The factor means in Table 17 show frontal bone length to increase from M1 level 2 to level 3, and then to decrease dramatically from level 3 to level 4. But the frontal bone length ANOVA is not quite significant either (P = 0.0628). It is difficult to decide if the pattern of means in Table 17, page 78, tells the true stury of frontal bone age changes, though the factor certainly undergoes some kind of post-adolescent change.

TABLE 24. NOTEWORTHY SPEARMAN'S CORRELATIONS FOR THE LARSON M1 VARIABLE

FACTOR (NO.)	SPEARMAN'S R	PROB
FRONTAL BONE LENGTH (13)	-0.1838	0.0778
INTERORBITAL BREADTH (15)	0.2107	0.0426

The same dilemma is encountered for interorbital breadth (Tables 17 and 24) as for frontal bone length. The highest factor score mean is associated with the middle level of Larson M1 wear. However, levels 3 and 4 of M1 have very similar factor means. It is therefore concluded that interorbital breadth increases between M1 levels 2 and 3 but there is no noteworthy change thereafter. This interpretation is supported by the Spearman's r (Table 24), which is positive and significant.

The ANOVAs suggested that three other factors varied with Larson M1 attrition, but these trends were not detected by the rank order correlations. Table 17 shows that the occipital curvature and size, and parietal size and profile factors have their highest means for the middle level of M1 wear and it is therefore not surprising that Spearman's r failed to detect a unidirectional change in these factors. On the other hand, the facial forwardness means clearly increase as Larson M1 increases. As seen in Table 16, page 78, the facial forwardness ANOVA was not quite statistically significant (P = 0.0733). This, together with the fact that Spearman's r failed to detect any pattern, suggests that there is no significant relationship between facial forwardness and first molar attrition among the Larson crania.

E. SUMMARY

The factor analysis presented few surprises or difficulties. Many of the factors obtained were the same as those of Howells (1973), though they were ordered differently in regard to the amount of within-groups variance each factor accounted for. This is not surprising because most of the data used were a portion of Howells' data set. All factors were easy to interpret.

It was possible to conduct 13 MANOVAs to test for effects of various tooth wear variables upon cranial factor structure. Noteworthy overall tooth wear effects were found in the following analyses: Berg M2, Tolai M2, Sully ANT, Sully M1, Sully M2, Larson ANT, and Larson M1.

Table 25 summarizes the specific changes of the face and cranium that are associated with dental attrition. These will be discussed in descending order of the frequency with which significant changes are indicated across the columns of Table 25. Interorbital breadth was found to increase significantly in all five Arikara

TABLE 25. SUMMARY OF ANOVA AND SPEARMAN'S RANK ORDER CORRELATION RESULTS[a]

FACTOR (NO.)	TOLAI	BERG	SULLY			LARSON	
	M2	M2	ANT	M1	M2	ANT	M1
FACIAL FORWARDNESS (1)		+	+		+	+?	
OCCIPITAL CURVATURE AND SIZE (4)	+						*
FACIAL HEIGHT (5)		+				+	
INTERORBITAL PROMINENCE (6)		+					
PARIETAL SIZE AND PROFILE (7)			+				*
FRONTAL PROFILE FLATNESS (10)			-	-	-	-	
SUBNASAL FLATNESS (12)			-	-		-	
FRONTAL BONE LENGTH (13)	+						*
INTERORBITAL BREADTH (15)			+	+	+	+	+
FORAMEN MAGNUM LENGTH (16)			-			*	
ORBIT SIZE (17)	+		+	+	+		
SUPRAORBITAL PROJECTION	+		+				
MASTOID LENGTH	+						
MASTOID WIDTH				+	+		

[a] + = factor score increases with higher attrition.

+? = unlikely but possible that factor score increases with higher attrition.

* = factor first increases, then decreases with higher attrition.

\- = factor score decreases with higher attrition.

analyses. Factor scores for frontal profile flatness were found to decrease with tooth wear in all Arikara analyses but that of Larson M1 attrition. Orbit size was positively associated with all three Sully attrition variables, as well as with Tolai M2. For Berg M2, Sully ANT, Sully M2, and perhaps Larson ANT it was discovered that facial forwardness increased with increasing wear. Analyses of subnasal flatness indicated that the subnasal area receded relative to the cheeks as attrition became more severe for Sully ANT, Sully M1, and Larson ANT. Positive associations were found between the following: facial height with Berg M2 and Larson ANT, supraorbital projection with Tolai M2 and Sully ANT, and mastoid width with Sully M1 and Sully M2.

A number of factors showed a significant unidirectional pattern of age change in one analysis, and a significant but discontinuous pattern of change in another analysis. Occipital curvature and size increased with Tolai M2 scores but was discontinuous for Larson M1. Parietal size and profile increased with higher levels of Sully ANT but was discontinuous in the Larson M1 analysis. The length of the frontal bone increased continually with increasing Tolai M2 scores, but was discontinous for the Larson M1 analysis. Finally, the length of the foramen magnum decreased as Sully ANT became progressively more severe, but showed a discontinuous pattern of association with Larson ANT. In all of these cases of discontinuity the middle level of tooth wear was associated with the highest mean factor score, and the higher and lower levels of wear had somewhat lower factor scores.

There were two other isolated findings. Interorbital prominence was positively associated with Berg M2 wear, as was mastoid length with Tolai M2.

CHAPTER VII

DISCUSSION

A. IMMEDIATE CONSIDERATION OF THE RESULTS

General Remarks

In Chapter VI much attention was given to the fact that some overall MANOVA tests (Table 3, page 69) for tooth wear effects warranted the more specific ANOVAs and Spearman's analyses, even though not all of these overall tests were significant at the 0.05 level. Judging from the results summarized in Table 25, it is clear that the decision to more carefully scrutinize these tooth wear effects was justifiable. There is far too much agreement between the columns of Table 25 than could be attributed to chance. For instance, orbit size changed with age in four of the analyses: Tolai M2, Sully ANT, Sully M1, and Sully M2. Furthermore, the direction of age change of orbit size in these four analyses was the same, although in only one analysis (Sully M1) was the MANOVA significant at the 0.05 level.

Even if we take the Sully and Larson collections to be representative of the same "race," it appears from Table 25 that there are some similarities between races in the pattern of age changes in the skull. Six factors were affected by post-adolescent growth in more than one race, and four of these factors (facial forwardness, facial height, orbit size and supraorbital projection) changed in the same direction in more than one race. The other two factors (occipital curvature and size, and frontal bone length) increased with age in one race, the Tolai, but showed a discontinuous pattern of age change in the Arikara. No similarities were noted between the Berg and the Tolai.

However, it is difficult to accurately judge the degree of interracial similarity with regard to the effects of aging on the skull. Table 2, page 68, indicates that the Arikara are better represented with regard to sample sizes, data balance, and range of tooth wear variation than are the other three groups. It is likely that better representation improves the chances of detecting age changes. This might explain why Tables 3, page 69, and 25 report fewer significant results for the Berg and Tolai, and none at all for the Yauyos.

Some remarks are in order regarding the Sully site archeology and the suitability of this series for the present analysis. In Chapter III it was explained that the Sully skulls were probably derived from several occupational components, and that this may bring into question their behavioral and genetic homogeneity. Cross-tabulations of tooth wear levels with occupational components showed a random distribution of skulls for both sexes and both wear variables. This makes it less likely that the reported tooth wear effects are due to genetic effects. It is also interesting that age-tooth wear effects made themselves apparent in spite of this source of noise among the Sully skulls.

Comparison Between Wear Variable Effects

Sully and Larson are the only two groups that can be used to assess the similarity between tooth wear variables regarding their associations with age changes. From Table 25 it can be seen that for the Larson sample six, or perhaps seven, factors were found to change with age, but only one, interorbital breadth, showed significant change in both the Larson ANT and Larson M1 analyses. Taken alone this indicates that anterior tooth wear and first molar wear have independent relationships with post-adolescent age changes in the skull, at least in the Larson population.

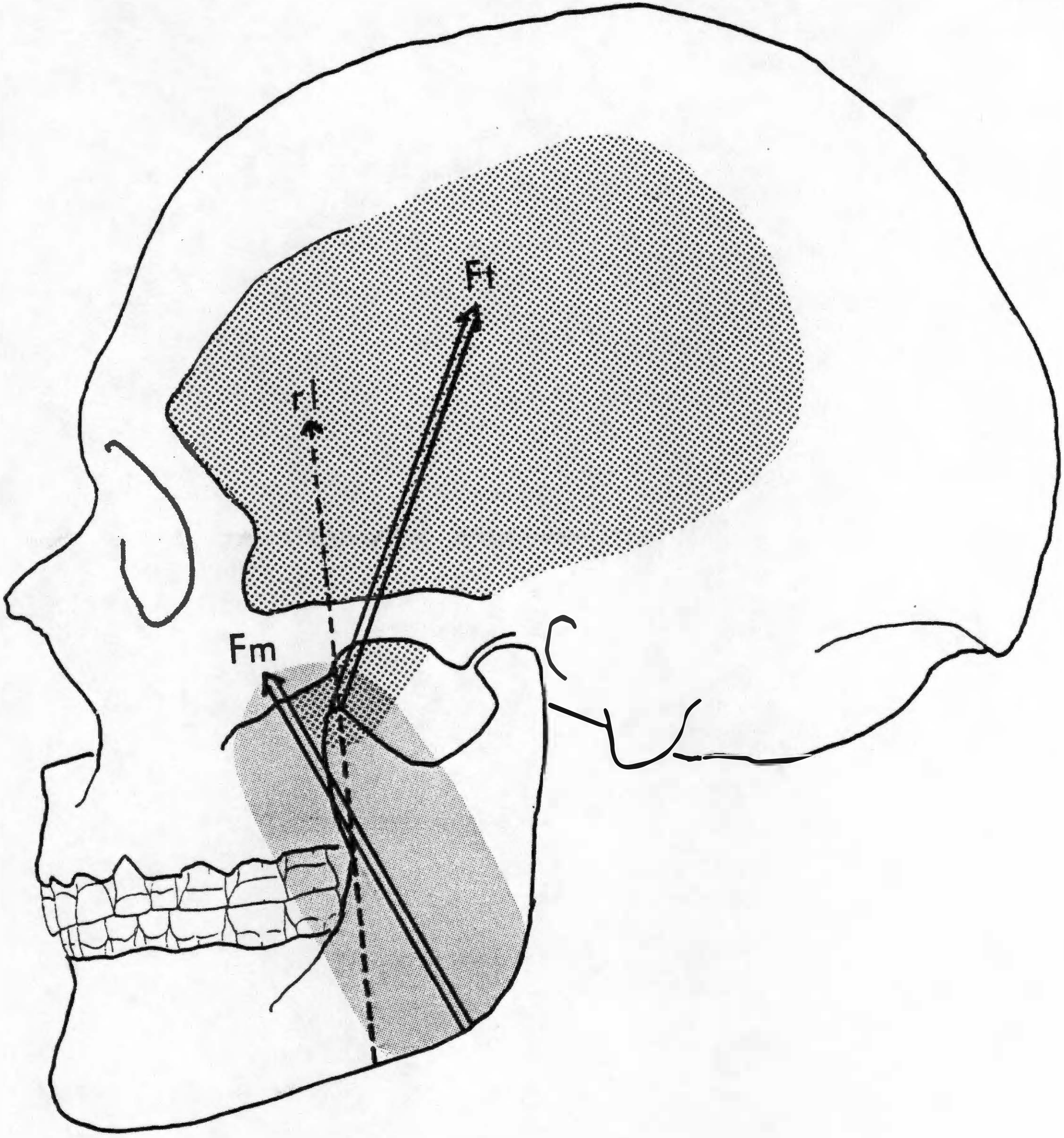
For the Sully sample there are three wear variables to compare in Table 25. Taken together, Sully ANT, M1 and M2 were significantly associated with nine factors. Sully ANT and M1 had similar relationships with four factors, but in four other cases only one or the other was associated with a factor. Sully ANT and M2 had similar relationships with four factors, but for three other factors only one or the other was involved. Finally, Sully M1 and M2 had similar relationships with four factors but differed on two.

For the Sully collection there appears to be more congruency between wear variables than among Larson crania. Still it is reasonable to assume that ANT, M1 and M2 are inter-correlated to some extent. Therefore, one might not expect their patterns of association with cranial transformations to be as different as they are for Sully and Larson. A possible explanation for these findings is that there is a particularly strong cause-and-effect relationship between a tooth wear variable and an age change with which it is associated. For example, within the Larson sample anterior tooth use may have stimulated growth in facial height, while chewing with the first molars produced changes in occipital curvature and size.

Dental Function Considerations

Several of the discussions in this section are accompanied by figures illustrating the variables of the craniometric factor under consideration, and the major muscles of mastication--the temporalis and masseter. These are illustrated in Figure 5, which is a lateral view craniostat drawing of a typical male Arikara skull. The figure also shows the average force vectors of these muscles and the results of these forces (adapted from Hylander 1972, Fig. 30). The internal pterygoid muscles are not pictured, though they are of great importance in biting and chewing. The direction of their force vectors is approximately the same as that of the masseters, as the pterygoids are directly medial to the masseters. The reader should keep Figure 5 in mind while trying to intuit what roles dental function could play in the age-related changes reported.

The major measurements of the facial forwardness factor are shown as narrow, straight lines in Figure 6. These measurements increased with age in the Berg M2, Sully ANT, Sully M2, and possibly the Larson ANT analyses. It is possible to interpret increased facial forwardness as a plastic response of the skull to the forces of biting and chewing. Imagine that the masseter and temporal muscles form a coronal ring around an elastic skull model. Contraction of the ring would tend to force the face forward just as hands might squeeze the end of an oblong balloon away from its main body. Perhaps as Berg and Arikara individuals aged their skulls lost the ability to maintain what might be assumed to be the optimum morphology of young adulthood because of tremendous masticatory forces. Such a response by the skull



Ft = temporalis force
Fm = masseter force
rl = their resultant

FIGURE 5. FORCE VECTORS OF MAJOR MUSCLES OF BITING AND CHEWING, ADAPTED FROM HYLANDER (1972:Figure 30)

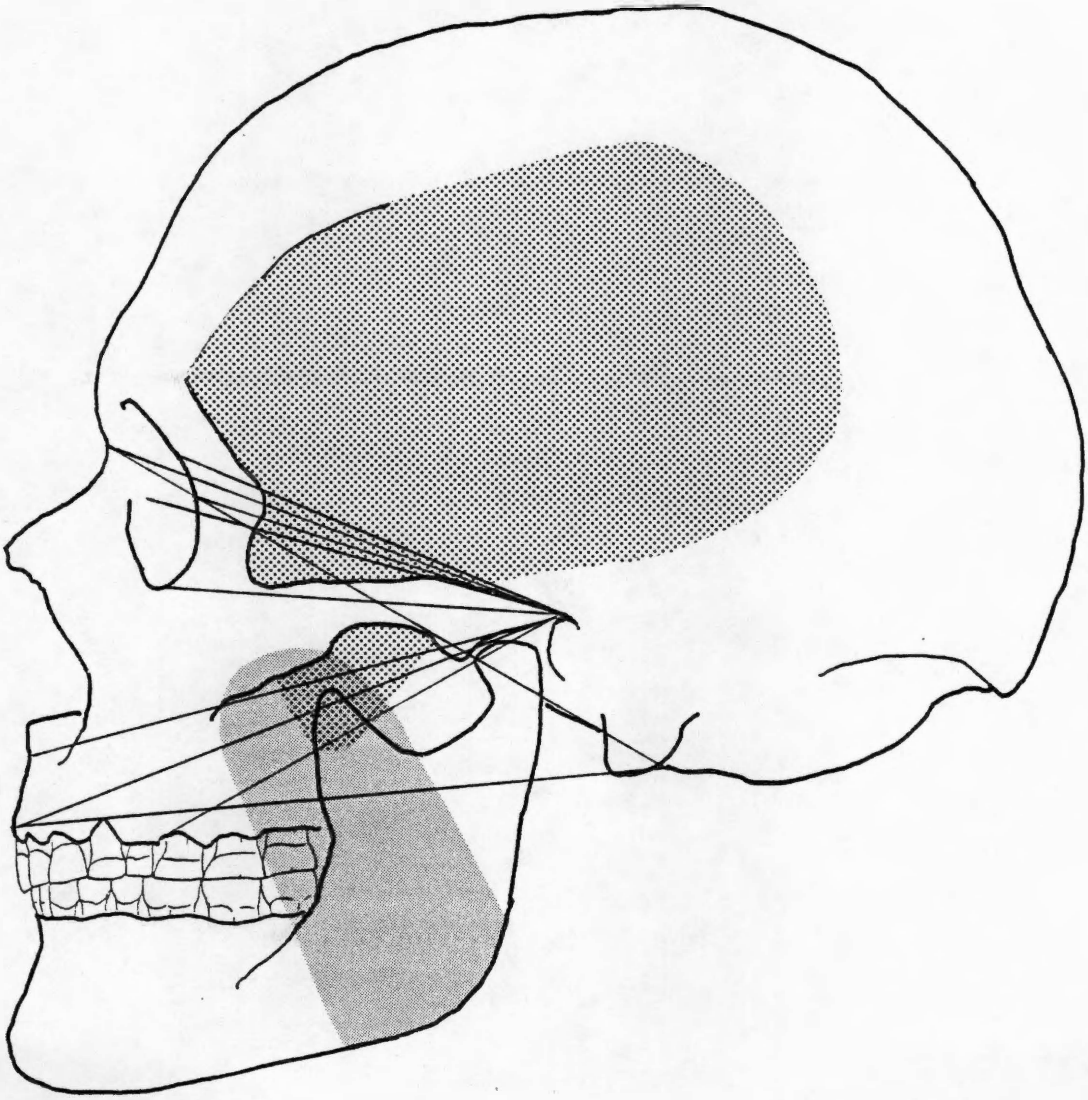


FIGURE 6. VARIABLES OF THE FACIAL FORWARDNESS FACTOR

to these forces would be complicated, in that it would probably involve many craniofacial bones and their interconnecting sutures. However, most of the growth would occur in the region connecting the splanchnocranium and neurocranium. The region is traversed by the resultant force vector in Figure 5. This again illustrates that the masticatory muscles are in a good position to effect an increase in facial forwardness.

Occipital curvature and size increased with higher levels of Tolai M2, and increased but then decreased with increasing Larson M1 scores. Wolpoff (1980) and Brose and Wolpoff (1971) have explained the significance of occipital morphology for the dental activities of fossil hominids and primitive modern peoples who use their teeth in non-masticatory tasks. Increased curvature and size, like the "bunning" of Neanderthal occipitals, provides an enlarged area for attachment of the nuchal muscles to the back of the head. The muscles maintain anterio-posterior head balance and are particularly important in counteracting anterior head tilt that results when teeth are used to grip objects being pulled forward or downward by the hands. These activities include softening of hides and the tearing of meat from bones (see Brace et al. 1981 for references). Perhaps such dental activity of the Tolai, as reflected by M2 wear, stimulated continued growth and development in the occipital region through exertion of the nuchal muscles. However, this line of reasoning cannot explain why occipital curvature and size first increased and then decreased in the Larson M1 ANOVA (Tables 16 and 17, page 78). Analysis of other skeletal samples is necessary to answer this question and to test the hypotheses presented here.

Facial height (or "upper" facial height, strictly speaking) increased as Berg second molar and Larson anterior tooth wear progressed. It is not clear how upper facial height could be related to dental function. The trend has been noted before in Caucasians (Israel 1967; Nasjleti and Kowalski 1975), but Ruff (1980) was unable to detect adult age changes in upper facial and nasal height measurements of Indian Knoll, Kentucky crania.

The interorbital area was involved in all but one analysis of Table 25, page 86. Interorbital prominence increased as Berg M2 scores increased, and interorbital breadth increased in all five Arikara tooth wear analyses. The latter findings are similar to Lasker's (1953) report of an age-related increase in interocular breadth in a cross-sectional sample of living Mexicans. There is a very logical explanation for the relationship of interorbital breadth and prominence with tooth wear. Endo (1966) has shown convincingly that there is a remarkable amount of compressive strain in the interorbital area when bite forces are transmitted through the skull. It is well known that compressive strain on bone surface tends to induce appositional growth (Bassett 1971). Thus, the age-related increase in interorbital area is interpreted here as an adaptive response to dental function.

The parietal size and profile factor is illustrated in Figure 7. The dotted lines are chords of reference and are not a part of the factor. For the Sully ANT analyses the parietal length measurements and the angle increased, while the subtense decreased with higher attrition scores. It is tempting to theorize that the temporalis muscles are somehow involved in the alterations of parietal size and

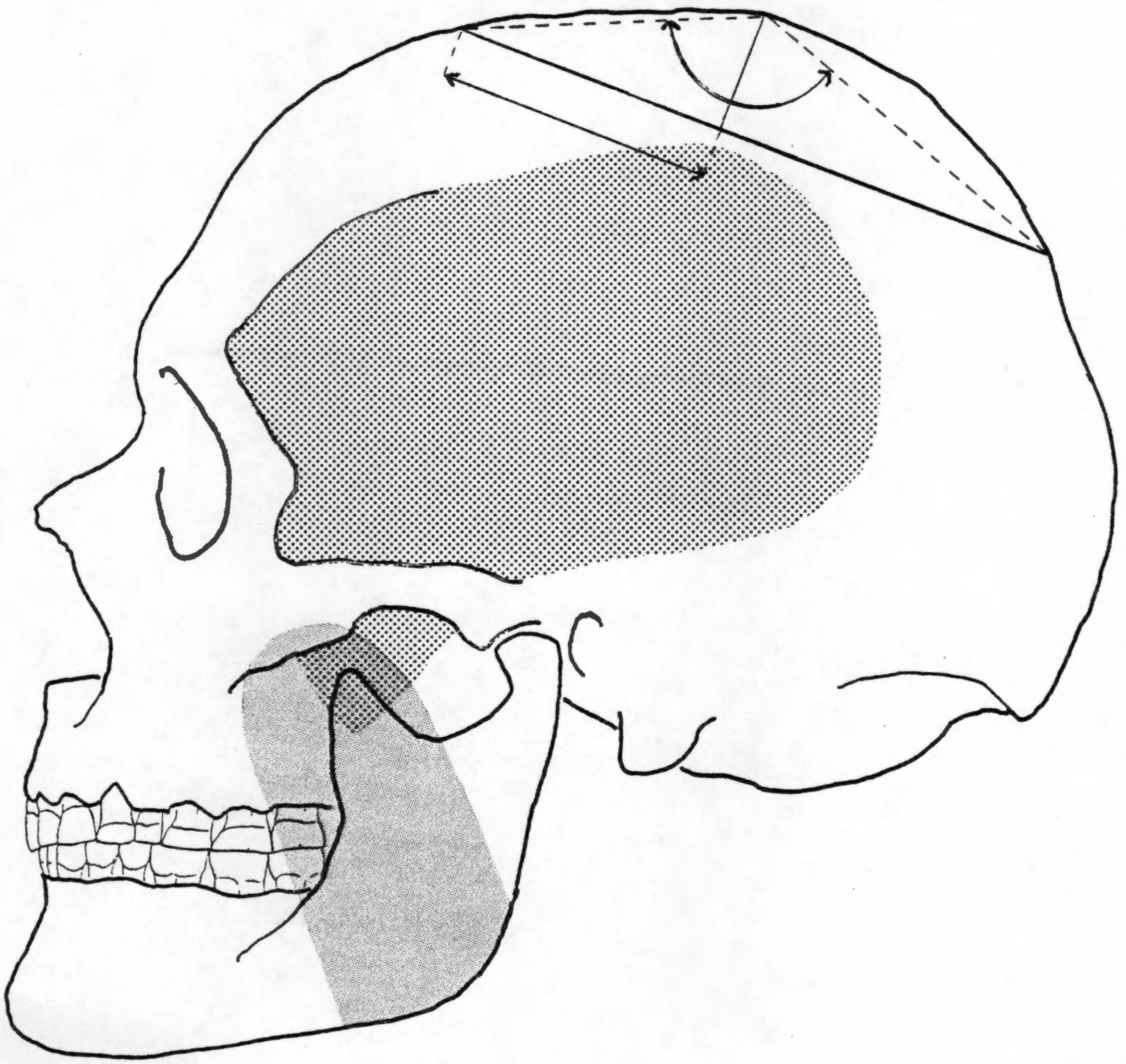


FIGURE 7. VARIABLES OF THE PARIETAL SIZE AND PROFILE FACTOR

shape. Unfortunately, for the Larson M1 analyses the trend between the third and fourth wear categories was the reverse of what it was for the Sully analyses. The role of the temporalis muscles might have been clearer had additional parietal measurements, not limited to the midsagittal plane, been used. Parietals are three-dimensional objects, and an appreciation for other aspects of their age-related alterations might clear the picture up.

The major variables of frontal profile flatness are depicted in Figure 8. As tooth wear becomes increasingly severe the subtense decreases and the angle increases significantly in four of the five Arikara analyses--no change was noted for Larson M1 attrition (Table 25, page 86). Unlike the parietal size and profile findings, the age-related trends are consistent from analysis to analysis. Also unlike the parietal analyses, several other measurements of the frontal bone that were not limited to the midsagittal plane were used. Thus, because of the properties of factor analysis we can be fairly certain that alterations of variables in Figure 8 occurred independently of other age-related changes (or stabilities) in the frontal bone.

Endo (1966) has shown that frontal profile verticalness is intimately related to how well the frontal bone can withstand masticatory stresses transmitted from the interorbital area. However, the relationship between frontal bone <u>verticalness</u> and <u>flatness</u> (as measured here) is unknown. If it turns out that vertical frontal bones are also flatter then the age-related changes discovered here could be viewed as adaptive responses to aggregate chewing forces.

The major variables of subnasal flatness are shown in Figure 9.

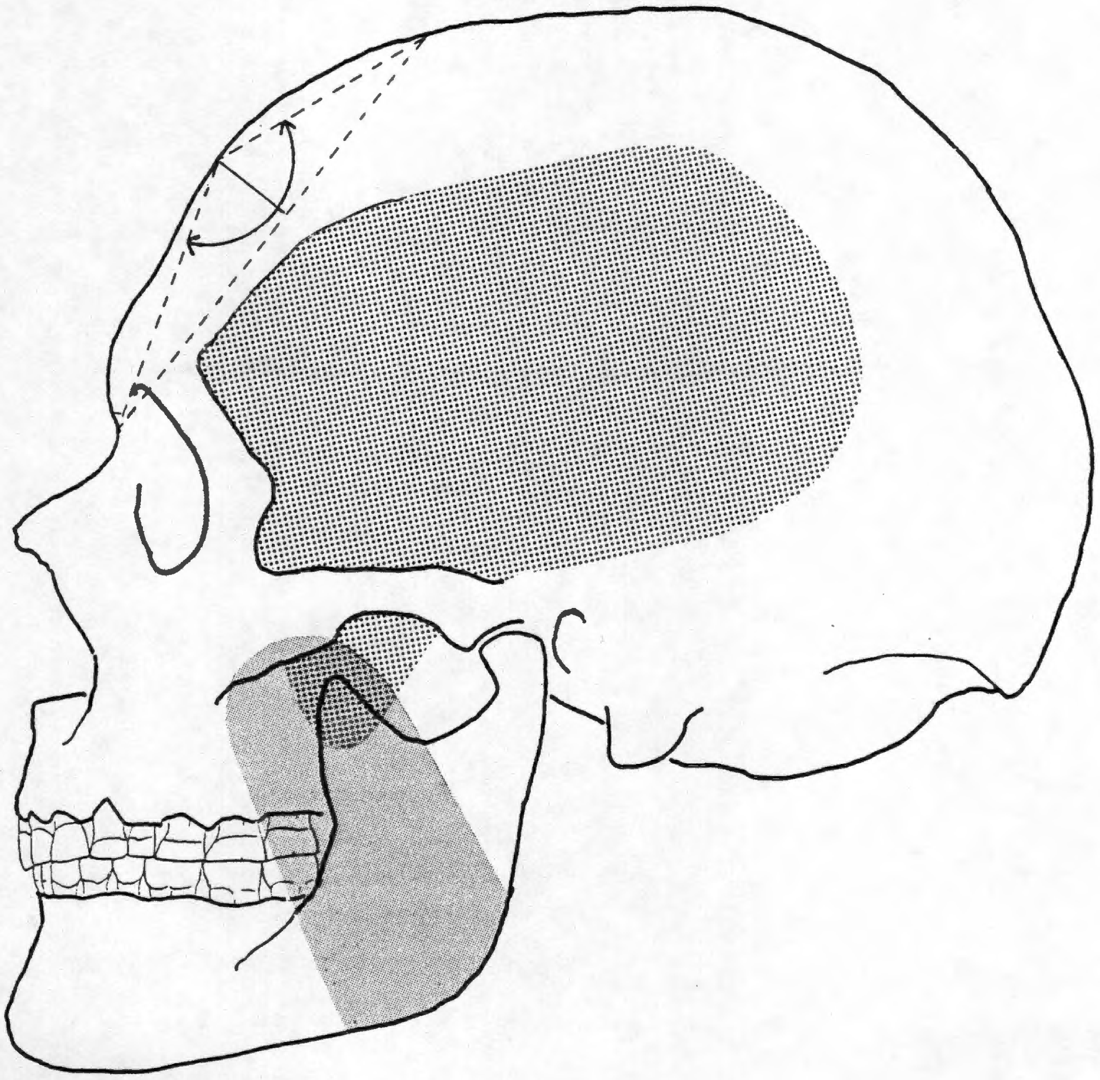


FIGURE 8. VARIABLES OF THE FRONTAL PROFILE FLATNESS FACTOR

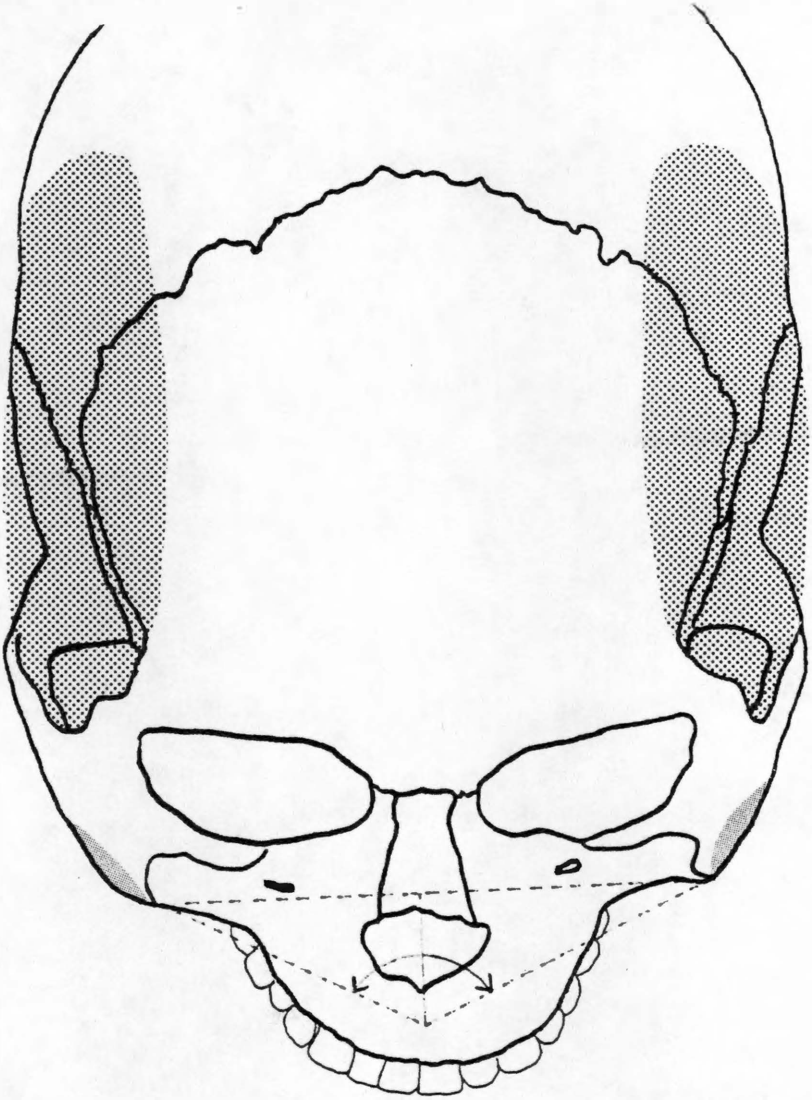


FIGURE 9. VARIABLES OF THE SUBNASAL FLATNESS FACTOR

The subtense decreases and the angle increases with higher tooth wear. This could be attributed to apposition of bone on the anterior part of the malars and the lateral part of the maxilla to either provide more attachment area for growing masseter muscles or to improve strain resistance in this area due to masseter activity. Another interpretation, not necessarily exclusive of the first, might be alveolar bone resorption in the area of subspinale. This resorption could very well be attributable to tooth socket shortening and continued eruption that Murphy (1959) found to accompany heavy attrition in Australians. Hylander (1977b) also related root resorption to attrition in his study of Indian Knoll dental arches. Peterson (1949, cited in Hylander 1977a and Cederquist and Dahlberg 1979) found among Greenland Eskimo crania that apical root resorption was associated with heavy dental wear, that it was limited to the anterior teeth, and that it was most apparent in the maxillary incisors. Whatever the case, the aging trend in subnasal flatness seems very likely to be related to dental function.

The length of the frontal bone, as measured from nasion to bregma, was positively associated with Tolai M2. The factor also showed a significant but discontinuous relationship with Larson M1, where frontal length increased and then decreased. Endo (1966) discovered that masticatory forces impose stresses and strains on the midsagittal part of the outer table of the frontal bone--there is compression vertically and tension horizontally. However, it is difficult to discern how an increase in nasion-bregma distance could be an adaptive or degenerative response to these forces. Still, because frontal bone length and flatness are associated with attrition in three of the groups examined, and because of the documented stresses and strains in this area there is a good chance that future research concentrating on the frontal bone will reveal a link between dental function and age changes in frontal morphology.

At this time no biomechanical explanation can be presented for the negative correlation of foramen magnum length with Sully ANT, or its discontinuous association with Larson ANT.

For Tolai M2 and all three Sully analyses orbit size increased with age. This is in harmony with the finding of Kokich (1976) that the orbital surfaces near the frontozygomatic sutures are resorptive in adulthood. Still, it is difficult to discern any adaptive or degenerative role of orbit size increase in adulthood.

The positive association of supraorbital projection with Tolai M2 and Sully ANT attrition can easily be explained as a growth response of the brow ridges to the significant stresses and strains that masticatory activity generates over the eyes (Endo 1966). Growth of the supraorbital tori would be likely to provide more resistance to dental functional forces in this area. In fact, the most viable explanation for large brow ridges in fossil hominids is that they are evolutionary adaptations to heavy use of the teeth in masticatory and non-masticatory activities (Smith and Ranyard 1980).

The positive associations of mastoid length with Tolai M2 and mastoid width with Sully M1 and M2 are interesting in the same vein that the occipital curvature and size analyses were. The sternocleidomastoid muscles insert on the mastoids. Their function is to turn the head from side to side and to flex the head and neck forward. In conjunction with the nuchal muscles the sternocleidomastoids maintain general head stability. With these functions in mind it is possible to relate mastoid size with the ethnographically documented use of teeth as vice grips for pulling, carrying, and holding heavy items, or exerting torsional forces on objects (see numerous references in Brose and Wolpoff 1971:1176). In these kinds of activities head stability must be maintained. The age-related increase in mastoid width can therefore be viewed as an adaptive response to aggregate dental functional activities.

Some colleagues have suggested that the dental function interpretations presented herein have reversed the roles of cause and effect. It may be that certain _genetically_ determined morphometric attributes render their bearers able to generate more biting force. Such skulls would therefore generate more dental attrition as the argument goes. There is nothing in the present analysis that can dismiss this line of reasoning outright. Still, care should be taken not to overemphasize the extent to which skull morphology determines behavior (i.e. dental function). Discussions of the hominid fossil record (e.g. Wolpoff 1980) stress that the evolution of morphological features such as robust mid-faces and jaws were _preceded_ by behavioral changes which necessitated their development. Likewise, it seems intuitively logical, but unprovable, that wider interorbital regions and flatter subnasal areas of some Arikara, for example, resulted from those persons exerting higher levels of dental force.

To view the matter from another angle, imagine the hypothetical situation of two Arikara females of the same age, and who differed only in their degree of subnasal flatness. Further, suppose that they executed similar dental tasks throughout their lives, such as softening of hides. If it can be assumed that a flatter subnasal area allows a stronger bite, then the female so endowed might have softened each hide more easily. But, as likely as not, the other woman would have chewed harder or longer to get the job done. Roughly similar amounts of dental attrition would have occurred, and we would not expect to be able to find any relationship between wear and morphology as was the case in this investigation. This discussion does not "prove" that cumulative dental function is the cause of morphological variability, but it is intended to argue that the reverse is unlikely.

B. RAMIFICATIONS FOR OTHER SKELETAL STUDIES

Anthropologists have used adult cranial measurements for a number of purposes other than the study of aging. These include: (1) explorations of the patterns of within- and between-race variation (Howells 1973; Gutlielmino-Matessi et al. 1979); (2) the determination of sex and race of unknown skulls (Giles and Elliot 1962, 1963); (3) studies of micro-evolution (Jantz 1973; Key 1982), and analyses of fossil hominids to discern their relationships. All of these endeavors suffer from a number of sources of error that are difficult to avoid (e.g. measurement error, dating error). This investigation and others have shown that there exists another source of background noise that sometimes _can_ be eliminated--age-related cranial variability. The issue cannot be stated more clearly than it was by Heathcote (1981):

> Surely those of us working in the classical wing of comparative human osteology need to do our utmost to enhance the

> signal-to-noise ratio of our studies. Our waters are murky enough. Along with such precautions as precision testing and giving careful consideration to trait selection, we should feel obliged to include age regression in our research protocols.

The importance of correcting for age-related variation probably differs a great deal from one application to another. For instance, it would probably not matter at all in determining whether or not Nigerian and British skulls differ significantly. However, in a forensic context it might improve the classification of borderline cases by a race-discriminant function for American whites and "blacks" (i.e. hybrids) if age variation was taken into account for both reference populations, as well as the unknown skulls.

Already a case can be made for the pertinence of the results to microevolutionary studies. Key and Jantz (1981)[1] analyzed the patterns of temporal and geographic variation of the principal component scores of Arikara crania from five archeological sites, including Sully and Larson. Of their six components showing significant temporal/geographic variation four are represented by factors in the present work: facial height, prognathism, frontal profile flatness, and foramen magnum size. Prognathism is the only one of these for which <u>no</u> indication of age change was found. In fact, Key and Jantz (1981) found that frontal profile flatness was the single most important component in explaining Arikara cranial variation through time. It is not likely that their general conclusions would have been drastically altered by age corrections. However, the precise nature of Arikara

---

[1] This study actually laid the groundwork for the statistical approach used herein.

skull microevolution might have been more clearly discernible, and this improved understanding might sooner make the cause of temporal change apparent.

The results also have relevance for the study of fossil hominids, particularly the interpretation of morphological changes that have taken place in the skull since the Neanderthal grade of human evolution. Some of the differences between archaic *Homo sapiens* (classic Neanderthals and their contemporaries) and anatomically modern *Homo sapiens* are mirrored by differences between old and young skulls within the samples of modern peoples analyzed here. Just as archaic *Homo sapiens* differed from modern peoples in having more forward faces, more curved occipitals, higher faces, broader and more prominent interorbital bones, more projecting brows and longer and wider mastoids (Wolpoff 1980), so too were older skulls found to differ from younger skulls.

To the extent that tooth wear measures cumulative dental function, these age-related changes may be due to dental function as explained above. With regard to the Neanderthals these features are thought to be part of a complex of traits adapted to generating greater bite forces via larger teeth and masticatory muscles (Brace 1979; Wolpoff 1980). Thus we see some resemblance between ontogenetic changes and phylogenetic adaptations. This does not mean that Middle-Late Pleistocene peoples evolved wide interorbital areas, for example, in a Lamarkian manner. However, if dental function can affect growth in individual modern adults then credence is lent to the view that natural selection could have brought about adaptations to dental function over tens of thousands of years. This line of reasoning appears more credible when we consider that pre-moderns were, indeed had to be, able to generate much greater biting forces than the Arikara.

Some paleontologists may feel that their dental function interpretations of human evolution need no support from studies such as this one on modern peoples. Nonetheless, it is interesting that this "masticatory function" hypothesis of pre-modern cranial evolution, first proposed by Hrdlička (1911; cited in Spencer and Smith 1981) and revived by Brace (1962, 1964), has been shown to have significance at the relatively infinitesimal level of a single human generation.

C. SUGGESTIONS FOR IMPROVEMENT AND FURTHER STUDY

The single most significant improvement in a study of this kind would be to examine larger samples. It would strengthen nearly every aspect of the analyses and interpretations.

Other ways of measuring dental attrition should be considered to supplement or replace the method used here. Walker (1978) has suggested using a planimeter to measure the area of exposed dentin in enlarged photographic images of the teeth. Data so collected would be of the interval type and could, therefore, greatly improve the accurateness and sensitivity of the statistical procedures.

Interproximal tooth wear (i.e. the wearing of adjacent teeth against each other) is known to be related to age and dental activity (Wolpoff 1971; Hinton 1982). Interproximal wear data should also be analyzed, sample sizes permitting.

Adjusting dental attrition measurements for tooth size would get rid of a heretofore unmentioned source of noise. For a given amount of dental function a small tooth is likely to wear more quickly than a large tooth. Therefore, ignoring tooth size variation may result in assigning persons of equivalent cumulative dental functional stress into different categories of tooth wear. Unfortunately, teeth are sometimes so severely worn that it is impossible to measure their maximum breadths or lengths (Goose 1963).

It would be interesting to contrast the extents of attrition of the first through third molars so as to measure rate of dental attrition in the fashion of Smith (1972) or Scott (1979). Ostensibly, wear rate is independent of age at death and may be associated with cranial variation in unique ways.

It may be worthwhile to pursue the use of attributes other than tooth wear for measuring masticatory functional stress on the skull. There is evidence that various dental and periodontal pathologies are sometimes related to excessive functional stress (Carranza 1979; Smith n.d.). The size of muscle origin or insertion areas might also be tested for an effect upon adult cranial variation (Hinton n.d.). To insure that muscle size reflects bite force potential, one might first adjust the muscle size data to correct for the effects of skull size and individual age at death. This strategy could ultimately allow independent tests for the effects of dental function (muscle size) and aging (tooth wear) on craniometric variation.

Additional cranial measurements, especially of the frontal and parietal bones, should be added to the data set to help clarify the precise effect of aging on the skull. Key (1982) has shown that basicranial variables are important in defining the principal component structure of the human skull, and these should also be added.

A case has been made for the possibility that variability of age profile between adult cranial samples may have an effect on the statistical "distance" between the samples. A good test would be to compute the Mahalanobis D^2s between the groups, and then to redo the computations after adjusting for age (i.e. tooth wear) differences to see if the effect of age is significant.

CHAPTER VIII

CONCLUSIONS

It is highly probable that adult age changes occurred in the morphometric characters of the Berg, Tolai and Arikara skulls. This conclusion is made despite the many sources of noise that were in effect for the analyses. No significant age changes were noted for the Yauyos, but this may be due to an inadequate amount of data. Most of the age-related changes discovered are not reported in studies of adult cranial aging in other human groups. This is probably due in part to the uniqueness of the methods used here, but may also reflect the extent to which the Berg, Tolai and Arikara differ genetically and behaviorally from other populations.

Contrary to some other reports, changes in both size and shape of the skull after adolescence have been discovered. Age alterations that were clearly apparent and continuous over age categories include the following: increases in facial forwardness (Berg, Sully and Larson), occipital curvature and size (Tolai), facial height (Berg and Larson), interorbital prominence (Berg) and breadth (Sully and Larson), and parietal size and profile (Sully), a flattening of the frontal bone in profile (Sully and Larson), an increase in frontal bone length (Tolai), a decrease in foramen magnum length (Sully), and increases in supraorbital projection (Tolai and Sully), mastoid length (Tolai) and mastoid width (Sully). The following showed discontinuous but significant changes over the levels of dental attrition in the Larson sample:

occipital curvature and size, parietal size and profile, frontal bone length, and foramen magnum length.

For undetermined reasons there were some differences between races and between tooth wear variables as to how the skull changed with age.

Strong support has been found for the hypothesis that some age-related changes are due to the cumulative effects of heavy biting and chewing forces. This explanation seems particularly appropriate for the increases in facial forwardness, interorbital breadth, interorbital prominence, supraorbital projection, mastoid width, and mastoid length, and the decrease in projection of the subnasal area. Some of these changes may be degenerative responses to masticatory forces (e.g. facial forwardness), some may be adaptive responses (e.g. interorbital breadth increase), while some could be seen either way (e.g. subnasal flattening).

The results have interesting implications for the interpretation of fossil hominid facial morphology. Support is found for the theory that features such as wide interorbital breadth and supraorbital projection were adaptations to intense biting forces.

There are indications that these age effects are significant enough to serve as sources of noise in other kinds of craniometric studies, such as microevolutionary analyses (e.g. Jantz 1973; Key 1982). As Hrdlička (1936:897) has warned us, ". . . henceforth thorough attention, in all anthropometric procedures on the adult, must be paid to age . . . ." The results here lend credence to this view. Hopefully, other studies will be undertaken to substantiate (or refute) this point.

LIST OF REFERENCES

LIST OF REFERENCES

Adeloye, A., K. R. Katlan and F. N. Silverman
1975 Thickness of the normal skull in the American blacks and whites. American Journal of Physical Anthropology 43: 23-30.

Arya, B. S., B. S. Savara, Q. D. Clarkson and D. R. Thomas
1973 Genetic variability of craniofacial dimensions. Angle Orthodontist 43:207-215.

Baer, M. J.
1956 Dimensional changes in the human head and face in the third decade of life. American Journal of Physical Anthropology 14:557-575.

Baring, T.
1817 A Tour through Italy, Sicily, Istria, Carniola, The Tyrol, and Austria, in 1814, Second Edition. Gale and Fenner, and Balwyn and Co., London.

Barr, A. J., J. H. Goodnight, J. P. Sall, W. H. Blair and D. M. Chilko
1979 SAS User's Guide. SAS Institute, Raleigh.

Barrett, M. J.
1958 Dental observations on Australian aborigines: continuously changing functional occlusion. Australian Dental Journal 3:39-52.

Bass, W. M.
1971 Human Osteology: A Laboratory and Field Manual of the Human Skeleton, Second Edition. Missouri Archeological Society, Columbia.

n.d. a. The Physical Anthropology of the Sully Site, 39SL4. Manuscript on file, Department of Anthropology, The University of Tennessee, Knoxville.

n.d. b. Evidence for a Possible Smallpox in a Protohistoric American Indian Village in South Dakota. Manuscript on file, Department of Anthropology, The University of Tennessee, Knoxville.

Bassett, C. A. L.
1971 Effect of force on skeletal tissues. In: Physiological Basis for Rehabilitative Medicine, edited by J. A. Downey and R. C. Darling, pp. 283-316, Saunders and Co., Philadelphia.

Beecher, R. M. and R. S. Corruccini
1981 Effects of dietary consistency on maxillary arch breadth in macaques. Journal of Dental Research 60:68.

Bodecker, C. F.
1925 A consideration of some of the changes in the teeth from young to old age. Dental Cosmos 67:543-549.

Boersma, H.
1974 Alteration of skull dimensions in aged persons. Journal of Dental Research 53:678-682.

von Bonin, G.
1936 On the craniology of Oceania: crania from New Britain. Biometrika 28:123-148.

Bowers, A. W.
1950 Mandan Social and Ceremonial Organization. University of Chicago Press, Chicago.

Brace, C. L.
1962 Refocusing on the Neanderthal problem. American Anthropologist 64:729-741.

1963 Structural reduction in evolution. American Naturalist 97:39-49.

1964 The fate of the "classic" Neanderthals: a consideration of hominid catastrophism. Current Anthropology 5:3-43.

1979 The Stages of Human Evolution, Second Edition. Prentice-Hall, Englewood Cliffs.

Brace, C. L. and P. E. Mahler
1971 Post-Pleistocene changes in the human dentition. American Journal of Physical Anthropology 34:191-204.

Brace, C. L. and S. Molnar
1967 Experimental studies in human tooth wear: I. American Journal of Physical Anthropology 27:213-222.

Brace, C. L. and A. Montagu
1977 Human Evolution: An Introduction to Biological Anthropology, Second Edition. Macmillan, New York.

Brace, C. L., A. S. Ryan and B. H. Smith
1981 Comment on: Tooth wear in La Ferrassie Man, by P-F. Puech. Current Anthropology 22:426-430.

Brose, D. S. and M. H. Wolpoff
1971 Early Upper Paleolithic Man and Late Middle Paleolithic tools. American Anthropologist 73:1156-1194.

Brothwell, D. R.
1972 Digging up Bones: The Excavation, Treatment and Study of Human Skeletal Remains, Second Edition. British Museum (Natural History), London.

Buchi, E. C.
1950 Anderungen der Korperform beim erwachsenen Menschen; eine Utersuchung nach der Individual Methode. Anthropologische Forschungen, Anthropologischen Gesellschaft in Wien 1:1-44.

Butler, R. J.
1969 The Heliocoidal Pattern of Dental Attrition in a Protohistoric Arikara Skeletal Population from the Northern Plains. Ph.D. dissertation, University of Kansas, Lawrence.

1972 Age-related variability in occlusal wear planes. American Journal of Physical Anthropology 36:381-390.

Carlsson, G. E., B. Bergman and B. Hedegard
1967 Changes in contour of the maxillary alveolar process under immediate dentures: a longitudinal clinical and x-ray cephalometric study covering five years. Acta Odontolongica Scandinavia 25:45-75.

Carlsson, G. E. and G. Persson
1967 Morphologic changes of the mandible after extraction and wearing of dentures: a longitudinal, clinical and x-ray cephalometric study covering five years. Odontologisk Revy 18:27-54.

Carranza, F. A. Jr.
1979 Glickman's Clinical Periodontology: Prevention, Diagnosis and Treatment of Periodontal Disease in the Practice of General Dentistry. W. B. Saunders, Philadelphia.

Cederquist, R. and A. A. Dahlberg
1979 Age changes in facial morphology of an Alaskan Eskimo population. OSSA 6:39-68.

Colby, W. B. and J. F. Cleall
1974 Cephalometric analysis of the craniofacial region of the Northern Foxe Basin Eskimos. American Journal of Physical Anthropology 40:159-170.

Coon, C. S.
1950 The Mountains of Giants: A Racial and Cultural Study of the North Albanian Mountain Ghegs. Papers of the Peabody Museum, Vol. 23(3), Harvard University, Cambridge.

Corruccini, R. S.
1973 Size and shape similarity coefficients based on metric characters. American Journal of Physical Anthropology 38:743-754.

1976 Calvarial shape relationships between fossil hominids. Yearbook of Physical Anthropology 1974 18:89-109.

Crichton, J. M.
1966 A multiple discriminant analysis of Egyptian and African Negro crania. In: Craniometry and Multivariate Analysis. Papers of the Peabody Museum, Vol. 57(1):45-67.

Dahlberg, A. A.
1960 The dentition of the first agriculturalists. American Journal of Physical Anthropology 18:243-256.

Davies, R. G.
1971 Computer Programming in Quantitative Biology. Academic Press, New York.

Dixon, W. J., M. B. Brown, L. Engelman, J. W. Frane and R. I. Jennrich
1979 BMDP-79; Biomedical Computer Programs, P-Series. University of California Press, Berkeley.

Droessler, J.
1981 Craniometry and Biological Distance: Biocultural Continuity and Change at the Late-Woodland-Mississippian Interface. Research Series, Vol. 1, Center for American Archaeology at Northwestern University, Evanston.

Endo, B.
1966 Experimental studies on the mechanical significance of the form of the human facial skeleton. Journal of the Faculty of Science, University of Tokyo, Section V, Anthropology 3:1-106.

Epstein, T. S.
1968 Capitalism, Primitive and Modern: Some Aspects of Tolai Economic Growth. Michigan State University Press, East Lansing.

Frane, J. W. and M. A. Hill
1974 Annotated Computer Output for Factor Analysis: a Supplement to the Write-up for Computer Program BMDP4M. Technical Report 8, Health Sciences Computing Facility, University of California, Los Angeles.

Garn, S. M.
1971 Human Races, Third Edition. Charles C. Thomas, Springfield.

Gilbert, B. M. and T. W. McKern
1973 A method for aging the female os pubis. American Journal of Physical Anthropology 38:31-38.

Giles, E. and O. Elliot
1962 Race identification from cranial measurements. Journal of Forensic Science 7:147-157.

1963 Sex determination by discriminant function analysis of crania. American Journal of Physical Anthropology 21: 53-68.

Goldstein, M. A.
1936 Changes in dimensions and form of the face and head with age. American Journal of Physical Anthropology 22:37-89.

Goose, D. H.
1963 Dental measurement: an assessment of its value in anthropological studies. In: Dental Anthropology, edited by D. R. Brothwell. Pergamon Press, London.

Gugleilmino-Matessi, C. R., P. Gluckman and L. L. Cavalli-Sforza
1979 Climate and the evolution of skull metrics in man. American Journal of Physical Anthropology 50:549-564.

Harman, H. H.
1976 Modern Factor Analysis, Third Edition. University of Chicago Press, Chicago.

Harris, J. E.
1973 Genetic factors in the shape of the craniofacial complex. Angle Orthodontist 43:107-111.

Harris, J. E., C. J. Kowalski, F. A. LeVasseur, C. E. Nasjleti and G. F. Walker
1977 Age and race as factors in craniofacial growth and development. Journal of Dental Research 56:266-274.

Hays, W. L.
1973 Statistics for the Social Sciences, Second Edition. Holt, Rinehart and Winston, New York.

Heathcote, G.
1981 Age regression of craniometric variates: a cross-sectional approach to the continuing growth of the craniofacial skeleton. Paper presented at the 9th Annual Meeting of the Canadian Association for Physical Anthropology, December, Banff.

Hellman, M.
1927 Changes in the human face brought about by development. International Journal of Orthodontia and Radiography 13:475-516.

Hinrichsen, G. J. and E. Storey
1968 The effect of force on bone and bones. Angle Orthodontist 38:155-165.

Hinton, P. C.
n.d. The relationship between tempromandibular joint size and cranial dimensions. Unpublished manuscript.

Hinton, R. J.
1979 Influence of Dental Function on Form of the Human Mandibular Fossa. Ph.D. dissertation, University of Michigan, Ann Arbor.

1981a Changes in articular eminence morphology with dental function. American Journal of Physical Anthropology 54:439-455.

1981b Temporomandibular joint size adaptations in prehistoric Tennessee Indians. Tennessee Anthropologist 6:89-111.

1982 Differences in interproximal and occlusal tooth wear among prehistoric Tennessee Indians: implications for masticatory function. American Journal of Physical Anthropology 57:103-116.

Holder, P.
1970 The Hoe and the Horse on the Plans: A Study of Cultural Development among the North American Indians. University of Nebraska Press, Lincoln.

Horowitz, S. L. and H. H. Shapiro
1951 Modification of mandibular structure following removal of the temporalis muscle in the rat. Journal of Dental Research 30:276-280.

Howells, W. W.
1957 The cranial vault: factors of size and shape. American Journal of Physical Anthropology 15:19-48.

1966 The Jomon populations of Japan: a study by discriminant analysis of Japanese and Ainu crania. In: Craniometry and Multivariate Analysis. Papers of the Peabody Museum, Vol. 57(1):1-43. Harvard University, Cambridge.

1973 Cranial Variation in Man: A Study by Multivariate Analysis of Patterns of Differences among Recent Human Populations. Papers of the Peabody Museum, Vol. 67. Harvard University, Cambridge.

Howells, W. W. and H. K. Bleibtreu
1970 Hutterite Age Differences in Body Measurements. Papers of the Peabody Museum, Vol. 57(2). Harvard University, Cambridge.

Hrdlička, A.

1910 Contribution to the anthropology of Central and Smith Sound Eskimo. Anthropological Papers of the American Museum of Natural History 5:175-285.

1911 Human dentition from the evolutionary standpoint. Dominion Dental Journal 23:403-422.

1925 The Old Americans. Williams and Wilkins, Baltimore.

1935 The Pueblos, with comparative data on the bulk of the tribes of the Southwest and Northern Mexico. American Journal of Physical Anthropology 20:235-460.

1936 Growth during adult life. Proceedings of the American Philosophical Society 76:847-897.

1940 Lower jaw. American Journal of Physical Anthropology 27:281-308.

Hunt, E.

1959 The continuing evolution of modern man. Cold Spring Harbor Symposia on Quantitative Biology 24:245-254.

Hurt, W. R. Jr.

1969 Seasonal economic and settlement patterns of the Arikara. Plains Anthropologist 14:32-37.

Hylander, W. L.

1972 The Adaptive Significance of Eskimo Craniofacial Morphology. Ph.D. dissertation, University of Chicago.

1977a The adaptive significance of Eskimo craniofacial morphology. In: Orofacial Growth and Development, edited by A. Dahlberg and T. Graber, pp. 129-169. Mouton, The Hague.

1977b Morphological changes in human teeth and jaws in a high-attrition environment. In: Orofacial Growth and Development, edited by A. Dahlberg and T. Graber, pp. 301-330. Mouton, The Hague.

Israel, H.

1967 Loss of bone and remodeling-redistribution in craniofacial skeleton with age. Federation Proceedings 26: 1723-1728.

1968 Continuing growth in human cranial skeleton. Archives of Oral Biology 13:133-138.

1973a Age factors and the pattern of change in craniofacial structures. American Journal of Physical Anthropology 39:111.

Israel, H.

1973b Recent knowledge concerning craniofacial aging. Angle Orthodontist 43:176-184.

1973c The failure of aging or loss of teeth to drastically alter mandibular angle morphology. Journal of Dental Research 52:83-90.

1977 The dichotomous pattern of craniofacial expansion during aging. American Journal of Physical Anthropology 47:47-52.

Jantz, R. L.

1970 Change and Variation in Skeletal Populations of Arikara Indians. Ph.D. dissertation, University of Kansas, Lawrence.

1973 Microevolutionary change in Arikara crania: a multivariate analysis. American Journal of Physical Anthropology 38:15-26.

1977 Craniometric relationships of Plains populations: historical and evolutionary implications. Plains Anthropologist 22:162-176.

Jantz, R. L. and D. W. Owsley

1982 Long bone growth variation among Arikara skeletal populations. Paper presented at the 51st Annual Meeting of the American Association of Physical Anthropologists, April, Eugene.

Keefe, E. K., D. P. Coffin, J. M. Moore, Jr., S. H. Scurlock and J. C. Shema

1976 Area Handbook for Austria. United States Government Printing Office, Washington, D.C.

Kendrick, G. S. and H. L. Risinger

1967 Changes in the anteroposterior dimensions of the human male skull during the third and fourth decade of life. Anatomical Record 159:77-82.

Kennedy, K. A. R.

1972 Comment on: Tooth wear and culture: a survey of tooth function among sone prehistoric populations. Current Anthropology 13:519.

Kerley, E. R.

1965 The microscopic determination of age in human bone. American Journal of Physical Anthropology 23:149-163.

Key, P. J.
1979 A Comparative Analysis of Cranial Variation in two Recent Human Populations. M.A. thesis, The University of Tennessee, Knoxville.

1982 Craniometric Relationships among Plains Indians: Culture-Historical and Evolutionary Implications. Ph.D. dissertation, The University of Tennessee, Knoxville.

Key, P. J. and R. L. Jantz
1981 A multivariate analysis of temporal change in Arikara craniometrics: a methodological approach. American Journal of Physical Anthropology 55:247-259.

Kim, J.
1975 Factor analysis. In: SPSS: Statistical Package for the Social Sciences, Second Edition, edited by N. A. Nie, C. H. Hull, J. G. Jenkins, K. Steinbrenner and D. H. Bent, pp. 468-508. McGraw-Hill, New York.

Kim, J. and C. W. Mueller
1978 Factor Analysis: Statistical Methods and Practical Issues. Quantitative Applications in the Social Sciences Series, No. 14. Sage, Beverly Hills.

Kokich, V. G.
1976 Age changes in the human frontozygomatic suture from 20 to 95 years. American Journal of Orthodontics 69:411-430.

Kowalski, C. J. and C. E. Nasjleti
1976 Upper face height-total face height ratio in adult American black males. Journal of Dental Research 55:913.

Kreiborg, S., B. L. Jensen, E. Joller and A. Björk
1978 Craniofacial growth in a case of congenital muscular dystrophy. American Journal of Orthodontics 74:207-215.

Krogman, W. M.
1962 The Human Skeleton in Forensic Medicine. Charles C. Thomas, Springfield.

Leigh, R. W.
1925a Dental pathology of the Eskimo. Dental Cosmos 67:884-898.

1925b Dental pathology of Indian tribes of varied environmental and food conditions. American Journal of Physical Anthropology 8:179-199.

1928 Dental pathology of aboriginal California. University of California Publications in American Archaeology and Ethnology 23:399-440.

Lasker, G. W.
1953 The age factor in bodily measurements of adult male and female Mexicans. Human Biology 25:50-63.

Lasker, G. W. and F. G. Evans
1961 Age, environment and migration: further anthropometric findings on migrant and non-migrant Mexicans. American Journal of Physical Anthropology 19:203-211.

Lehmer, D. J.
1971 Introduction to Middle Missouri Archaeology. National Park Service, Washington, D.C.

Lewis, A. B. and A. F. Roche
1977 The saddle angle: cinstancy or change? Angle Orthodontist 47:46-54.

Lin, P. M.
1973 A study of Arikara Skeletal Populations by Multivariate Analysis. Ph.D. dissertation, University of Kansas, Lawrence.

McKern, T. W. and T. D. Stewart
1957 Skeletal Age Changes in Young American Males. Analyzed from the Standpoint of Age Identification. Environmental Protection Research Division (Quartermaster Research and Development Center), Technical Report EP-45, United States Army, Natick.

Miles, A. E. W.
1963 The dentition in the assessment of individual age in skeletal material. In: Dental Anthropology, edited by D. R. Brothwell, pp. 191-209. Pergamon Press, London.

Molnar, S.
1968 Experimental studies of human tooth wear: II. American Journal of Physical Anthropology 28:361-368.

1971 Human tooth wear, tooth function and cultural variability. American Journal of Physical Anthropology 34:27-42.

1972 Tooth wear and culture: a survey of tooth function among some prehistoric populations. Current Anthropology 13: 511-526.

Moore, W. J.
1965 Masticatory function and skull growth. Journal of Zoology 146:123-131.

Morrison, D. F.
1976 Multivariate Statistical Methods. McGraw-Hill, New York.

Moss, M. L.
1957 Experimental alteration of sutural morphology. Anatomical Record 127:569-590.

1961 Extrensic determination of sutural morphology in the rat calvaria. Anatomical Redord 44:263.

Moss, M. L. and R. W. Young
1960 A functional approach to craniology. American Journal of Physical Anthropology 18:281-292.

Müller, W.
1905 Beiträge zur Kraniologie der NeuBritainnier. Mitteilungen aus dem Museum für Völkerkunde in Hamburg. 5. Beiheft zum Jahrbuch der Hamburgischen Wissenschaftlichen Anstalten 23:71-187.

Murphy, T.
1959 Compensatory mechanisms in facial height adjustment to functional tooth attrition. Australian Dental Journal 4:312-323.

Nakata, M., P. Yu, B. Davis and W. Nance
1974 Genetic determinants of cranio-facial morphology: a twin study. Annals of Human Genetics 37:431-443.

Nasjleti, C. E. and C. J. Kowalski
1975 Stability of upper face height-total face height ratio with increasing age. Journal of Dental Research 54:1241.

Oppenheimer, A.
1964 Tool use and crowded teeth in Australopithecinae. Current Anthropology 5:419-421.

Owsley, D. W.
1975 A Demographic Analysis of Skeletons from the Larson Site (39WW2), Walworth County, South Dakota. M.A. thesis, The University of Tennessee, Knoxville.

Owsley, D. W. and R. L. Jantz
1978 Intracemetery morphological variation in Arikara crania from the Sully site (39SL4), Sully County, South Dakota. Plains Anthropologist 23:139-147.

Parchappe, R.
1836 Recherches sur l'Encéphale; Vol. I, du Volume de la Tête et l'Encéphale chez l'Homme. Paris.

Parkinson, R.
1887 Im Bismark Archipel. Erlaubnisse und Beobachtungen auf der Insel Neu-Pommern (Neu-Britannien). Leipzig.

Parkinson, R.
1907 Dreissig Jahre in der Südsee. Strecker and Schröder, Stuttgart.

Pedersen, P. O.
1949 The East Greenland Eskimo dentition. Medelelser om Gronland 142:1-244.

Pfitzner, W.
1899 Social-anthropologische studien. I. Der einfluss des Lebensalters auf die Anthropologischen charactere. Zeitschrift fur Morphologie und Anthropologie 1:325-377.

Phenice, T. W.
1969 A newly developed visual method of sexing the *Os pubis.* American Journal of Physical Anthropology 30:297-302.

Pratt, L. W.
1943 Experimental masseterectomy in the laboratory rat. Journal of Mammalogy 24:204-211.

Price, W. A.
1939 Nutrition and Physical Degeneration: A Comparison of Primitive and Modern Diets and Their Effects. P. B. Hoeber, New York.

Randall, F. E.
1949 Age changes in young adult Army males. Human Biology 21:187-198.

Roberts, F. H. H. Jr.
1960 Seventy-sixth Annual Report of the Bureau of American Ethnology, 1958-59, pp. 1-41.

Ruff, C. B.
1980 Age differences in craniofacial dimensions among adults from Indian Knoll. Kentucky. American Journal of Physical Anthropology 53:101-108.

Salisbury, R. F.
1970 Vunamami: Economic Transformation in a Traditional Society. University of California Press, Berkeley.

Schour, I. and M. Massler
1941 The development of the human dentition. Journal of the American Dental Association 21:1153-1160.

Scott, E. C.
1979 Principal axis analysis of dental attrition data. American Journal of Physical Anthropology 51:203-212.

Shapiro, H. L.
1929 Contributions to the craniology of Central Europe. I. Crania from Greifenberg in Carinthia. Anthropological Papers of the American Museum of Natural History 31:1-120.

Smith, F. H.
1976a On anterior tooth wear at Krapina and Ochoz. Current Anthropology 17:167-168.

1976b The Neanderthal Remains from Krapina: A Descriptive and Comparative Study. Department of Anthropology Reports of Investigations, No. 15, The University of Tennessee, Knoxville.

Smith, F. H. and G. C. Ranyard
1980 Evolution of the supraorbital region in Upper Pleistocene fossil hominids from South Central Europe. American Journal of Physical Anthropology 53:589-610.

Smith, M. O.
n.d. Patterns of Association between Oral Health Status and Subsistence: A Study of Aboriginal Skeletal Populations from the Tennessee Valley Area. Ph.D. dissertation in preparation, The University of Tennessee, Knoxville.

Smith, P.
1972 Diet and attrition in the Natufians. American Journal of Physical Anthropology 37:233-238.

1976 Dental pathology in fossil hominids: What did Neanderthals do with their teeth? Current Anthropology 17:149-151.

Sneath, P. H. and R. R. Sokal
1973 Numerical Taxonomy: The Principles and Practice of Numerical Classification. W. H. Freeman, San Francisco.

Snow, C. E.
1948 Indian Knoll Skeletons. University of Kentucky Reports in Anthropology 4:377-554.

Sokal, R. E. and F. J. Rohlf
1969 Biometry: The Principles and Practices of Statistics in Biological Research. W. H. Freeman, San Francisco.

Spencer, F. and F. H. Smith
1981 The significance of Ales Hrdlička's "Neanderthal Phase of Man": a historical and current assessment. American Journal of Physical Anthropology 56:435-459.

Suchey, J. M.
1977 Problems in the aging of females using the pubic symphysis. Paper read at the Annual Meeting of the American Academy of Forensic Science, February, San Diego.

Susanne, C.
1977 Individual age changes of the morphological characteristics. Journal of Human Evolution 6:181-189.

Tallgren, A.
1974 Neurocranial morphology and ageing: a longitudinal roetgen cephalometric study of adult Finnish women. American Journal of Physical Anthropology 41:285-294.

Tatsuoka, M. M.
1971 Multivariate Analysis: Techniques for Educational and Psychological Research. Wiley and Sons, New York.

Thompson, J. L. and G. S. Kendrick
1964 Changes in the vertical dimensions of the human male skull during the 3rd and 4th decades of life. Anatomical Record 150:209-214.

Todd, T. W.
1924 Thickness of the male white cranium. Anatomical Record 27:245-256.

Walker, P. L.
1978 A quantitative analysis of dental attrition rates in the Santa Barbara channel area. American Journal of Physical Anthropology 48:101-106.

Washburn, S. L.
1946 The effect of removal of the zygomatic arch in the rat. Journal of Mammology 27:169-172.

1947a The relation of the temporal muscle to the form of the skull. Anatomical Record 99:239-248.

1947b The effect of the temporal muscle on the form of the mandible. Journal of Dental Research 26:174.

Watt, D. G. and C. H. M. Williams
1951 The effects of the physical consistency of food on the growth and development of the maxilla of the rat. American Journal of Orthodontics 37:895-928.

Weakley, W. F.
1971 Tree-ring dating and archaeology in South Dakota. Plains Anthropologist Memoir 8, Part 2, 16:1-51.

Weidenreich, F.
1941 The brain and its roles in the phylogenetic transformation of the human skull. Transactions of the American Philosophical Society 31:321-442.

Wissler, C.
1927 Age changes in anthropological characters in childhood and adult life. Proceedings of the American Philosophical Society 66:431-438.

Wolpoff, M. H.
1971 Interstitial wear. American Journal of Physical Anthropology 34:205-228.

1980 Paleoanthropology. Knopf, New York.

APPENDIX

TABLE A-1. DESCRIPTIVE STATISTICS OF THE BERG MALE CRANIOMETRICS (IN MM).

VARIABLE		CODE NAME	N	MEAN	VARIANCE	STD. DEV.	RANGE.	SKEWNESS	KURTOSIS
1	GLAB-OCC L	GOL	56	180.3	54.0	7.3	167.0 - 198.0	0.555	-0.300
2	NASIO-OCC L	NOL	56	177.3	55.3	7.4	164.0 - 197.0	0.625	-0.022
3	BAS-NAS L	BNL	56	98.6	20.4	4.5	90.0 - 110.0	0.079	-0.359
4	BAS-BREG HT	BBH	56	130.3	18.6	4.3	119.0 - 141.0	-0.107	0.287
5	MAX CRAN BR	XCB	56	147.6	30.5	5.5	133.0 - 161.0	0.060	-0.051
6	MAX FRON BR	XFB	56	124.6	26.7	5.2	113.0 - 135.0	0.037	-0.742
7	BISTEPH BR	STB	56	122.7	37.4	6.1	112.0 - 134.0	-0.064	-1.098
8	BIZYGO BR	ZYB	56	135.6	23.9	4.9	124.0 - 148.0	0.364	-0.013
9	BIAURIC BR	AUB	56	127.5	29.4	5.4	115.0 - 140.0	0.120	0.438
10	MIN CRAN BR	WCB	56	74.8	17.6	4.2	66.0 - 84.0	-0.084	-0.643
11	BIASTER BR	ASB	56	113.6	18.9	4.3	104.0 - 127.0	0.129	0.414
12	BAS-PROSTH L	BPL	56	93.8	32.4	5.7	81.0 - 108.0	0.605	0.494
13	NAS-PROSTH H	NPH	56	67.9	17.4	4.2	56.0 - 79.0	-0.165	0.442
14	NASAL HT	NLH	56	51.7	8.6	2.9	44.0 - 58.0	-0.141	-0.253
15	ORBIT HT (L)	OBH	56	33.8	3.4	1.8	29.0 - 39.0	0.320	0.589
16	ORB BR (L)	OBB	56	40.1	2.1	1.4	37.0 - 44.0	0.223	-0.058
17	BIJUGAL BR	JUB	56	117.1	14.5	3.8	109.0 - 124.0	0.030	-0.737
18	NASAL BR	NLB	56	25.5	3.9	2.0	22.0 - 31.0	0.499	0.124
19	PALATE BR	MAB	56	63.9	10.5	3.2	56.0 - 72.0	-0.013	0.253
20	MASTOID HT	MDH	56	28.3	7.8	2.8	22.0 - 36.0	0.026	-0.120
21	MASTOID WDTH	MDB	56	13.1	2.1	1.5	10.0 - 17.0	0.166	-0.163
22	BIMAXILL BR	ZMB	56	93.3	18.6	4.3	81.0 - 104.0	-0.065	0.333
23	ZYGOMAX SUBT	SSS	56	22.7	7.0	2.6	17.0 - 29.0	-0.012	-0.420
24	BIFRONT BR	FMB	56	99.6	11.1	3.3	92.0 - 107.0	0.146	-0.235
25	NAS-FRON SUB	NAS	56	18.3	5.4	2.3	12.0 - 24.0	-0.167	-0.063
26	BIORBITAL BR	EKB	56	98.7	10.3	3.2	92.0 - 105.0	-0.087	-0.721
27	DACRYON SUBT	DKS	56	10.4	3.5	1.9	5.0 - 14.0	-0.409	0.302
28	INTERORB BR	DKB	56	22.9	6.3	2.5	18.0 - 32.0	0.685	1.570
29	NAS-DAC SUBT	NDS	56	11.5	2.0	1.4	9.0 - 16.0	0.431	0.549
30	SIMOTIC CHRD	WNB	56	9.4	4.2	2.0	5.4 - 14.2	0.318	-0.224
31	SIMOTIC SUBT	SIS	56	4.7	1.9	1.4	0.4 - 7.3	-0.414	0.317
32	MALR L (INF)	IML	56	35.7	11.4	3.4	30.0 - 43.0	0.350	-0.742
33	MALR L (MAX)	XML	56	53.7	10.8	3.3	47.0 - 61.0	0.359	-0.554
34	MALAR SUBT	MLS	56	10.5	2.3	1.5	7.0 - 15.0	0.142	0.361
35	CHEEK HEIGHT	WMH	56	23.1	6.1	2.5	17.0 - 27.0	-0.654	-0.175

TABLE A-1 CONTINUED

VARIABLE	CODE NAME	N	MEAN	VARIANCE	STD. DEV.	RANGE	SKEWNESS	KURTOSIS
36 SUPORB PROJ	SOS	56	6.7	1.4	1.2	4.0 - 9.0	-0.019	-0.404
37 GLABEL PROJ	GLS	56	3.6	1.0	1.0	2.0 - 6.0	0.241	-0.730
38 FOR MAGNUM L	FOL	56	39.0	9.5	3.1	33.0 - 50.0	0.602	1.432
39 NAS-BREG CHD	FRC	56	111.1	15.9	4.0	100.0 - 122.0	-0.062	0.470
40 NAS-BREG SUB	FRS	56	27.1	6.6	2.6	21.0 - 33.0	-0.060	-0.227
41 NAS-SUB FRAC	FRF	56	50.2	10.4	3.2	43.0 - 57.0	0.090	-0.433
42 BREG-LAM CHD	PAC	56	110.1	22.2	4.7	99.0 - 120.0	-0.046	-0.091
43 BREG-LAM SUB	PAS	56	24.1	8.1	2.8	17.0 - 30.0	-0.053	-0.144
44 BREG-SUB FRC	PAF	56	58.5	20.2	4.5	47.0 - 68.0	-0.340	0.166
45 LAM-OPIS CHD	OCC	56	94.0	27.3	5.2	79.0 - 105.0	-0.384	0.025
46 LAM-OPIS SUB	OCS	56	28.5	11.5	3.4	21.0 - 38.0	0.304	0.370
47 LAM-SUB FRAC	OCF	56	48.3	39.4	6.3	36.0 - 66.0	0.318	-0.123
48 VERTEX RAD	VRR	56	120.8	12.7	3.6	111.0 - 128.0	-0.171	0.004
49 NASION RAD	NAR	56	94.9	14.7	3.8	87.0 - 103.0	0.127	-0.347
50 SUBSPINAL RD	SSR	56	93.2	22.2	4.7	82.0 - 105.0	-0.105	-0.037
51 PROSTHION RD	PRR	56	98.1	22.7	4.8	87.0 - 110.0	-0.097	-0.096
52 DACRYON RAD	DKR	56	82.6	11.6	3.4	76.0 - 90.0	0.035	-0.308
53 ZYGORBIT RAD	ZOR	56	79.8	13.6	3.7	72.0 - 89.0	-0.105	-0.297
54 FRONTOMAL RD	FMR	56	77.0	9.7	3.1	70.0 - 83.0	-0.035	-0.734
55 ECTOCONCH RD	EKR	56	71.2	9.3	3.1	64.0 - 78.0	-0.072	-0.476
56 ZYGOMAX RAD	ZMR	56	71.1	13.7	3.7	64.0 - 82.0	0.374	0.219
57 M1 ALVEOL RD	AVR	56	78.5	19.7	4.4	69.0 - 91.0	0.277	-0.139
58 NASANG BA-PR	NAA	56	65.6	17.4	4.2	57.0 - 75.0	0.344	-0.424
59 PROSAN NA-BA	PRA	56	73.1	8.1	2.8	66.0 - 78.0	-0.377	-0.502
60 BASANG NA-PR	BAA	56	41.3	8.6	2.9	35.0 - 48.0	-0.222	-0.537
61 NASANG BA-BR	NBA	56	76.5	10.8	3.3	65.0 - 83.0	-0.491	1.273
62 BASANG NA-BR	BBA	56	56.1	9.5	3.1	49.0 - 64.0	0.100	-0.188
63 ZYGOMAX ANG	SSA	56	128.1	28.2	5.3	117.0 - 141.0	0.030	-0.375
64 NAS-FRON ANG	NFA	56	139.8	19.4	4.4	132.0 - 152.0	0.424	-0.439
65 DACRYAL ANG	DKA	56	149.9	27.6	5.3	141.0 - 165.0	0.535	0.149
66 NAS-DACR ANG	NDA	56	89.7	79.5	8.9	71.0 - 111.0	-0.057	-0.151
67 SIMOTIC ANG	SIA	56	92.0	339.5	18.4	56.0 - 163.0	1.373	3.392
68 FRONTAL ANG	FRA	56	127.7	14.1	3.8	118.0 - 136.0	-0.006	0.030
69 PARIETAL ANG	PAA	56	132.6	17.7	4.2	124.0 - 143.0	-0.003	-0.262
70 OCCIPITAL AN	OCA	56	117.2	30.6	5.5	102.0 - 131.0	-0.339	0.842

TABLE A-2. DESCRIPTIVE STATISTICS OF THE BERG FEMALE CRANIOMETRICS (IN MM)

VARIABLE		CODE NAME	N	MEAN	VARIANCE	STD. DEV.	RANGE			SKEWNESS	KURTOSIS
1	GLAB-OCC L	GOL	53	170.5	42.4	6.5	155.0	-	181.0	-0.342	-0.754
2	NASIO-OCC L	NOL	53	168.5	43.0	6.6	153.0	-	180.0	-0.341	-0.493
3	BAS-NAS L	BNL	53	92.9	14.6	3.8	84.0	-	100.0	-0.235	-0.722
4	BAS-BREG HT	BBH	53	124.5	22.8	4.8	115.0	-	135.0	0.244	-0.487
5	MAX CRAN BR	XCB	53	140.4	21.4	4.6	131.0	-	152.0	0.376	-0.089
6	MAX FRON BR	XFB	53	118.7	22.1	4.7	110.0	-	131.0	0.223	-0.361
7	BISTEPH BR	STB	53	117.7	24.1	4.9	109.0	-	128.0	0.058	-0.769
8	BIZYGO BR	ZYB	53	126.4	15.8	4.0	117.0	-	133.0	-0.240	-0.848
9	BIAURIC BR	AUB	53	120.3	19.8	4.4	110.0	-	129.0	0.220	-0.556
10	MIN CRAN BR	WCB	53	71.1	13.3	3.7	63.0	-	81.0	0.098	-0.053
11	BIASTER BR	ASB	53	108.2	24.5	4.9	98.0	-	123.0	0.485	0.743
12	BAS-PROSTH L	BPL	53	89.9	26.5	5.1	82.0	-	100.0	-0.004	-1.136
13	NAS-PROSTH H	NPH	53	63.5	16.4	4.0	52.0	-	72.0	-0.230	0.214
14	NASAL HT	NLH	53	48.2	8.8	3.0	42.0	-	56.0	0.306	-0.194
15	ORBIT HT (L)	OBH	53	32.8	3.5	1.9	28.0	-	37.0	-0.108	0.096
16	ORB BR (L)	OBB	53	38.4	1.4	1.2	36.0	-	42.0	0.531	0.734
17	BIJUGAL BR	JUB	53	111.1	12.9	3.6	103.0	-	118.0	-0.160	-0.692
18	NASAL BR	NLB	53	24.9	2.9	1.7	22.0	-	30.0	0.591	0.184
19	PALATE BR	MAB	53	60.6	8.9	3.0	55.0	-	66.0	0.183	-0.925
20	MASTOID HT	MDH	53	25.6	6.7	2.6	18.0	-	31.0	-0.527	0.440
21	MASTOID WDTH	MDB	53	11.5	1.7	1.3	8.0	-	15.0	-0.024	0.488
22	BIMAXILL BR	ZMB	53	89.5	14.8	3.9	80.0	-	98.0	0.024	-0.246
23	ZYGOMAX SUBT	SSS	53	21.9	8.4	2.9	17.0	-	30.0	0.352	-0.336
24	BIFRONT BR	FMB	53	95.0	8.0	2.8	89.0	-	101.0	-0.054	-0.598
25	NAS-FRON SUB	NAS	53	16.8	5.2	2.3	12.0	-	23.0	0.477	0.042
26	BIORBITAL BR	EKB	53	95.2	7.1	2.7	89.0	-	101.0	0.092	-0.398
27	DACRYON SUBT	DKS	53	9.9	4.9	2.2	6.0	-	17.0	0.698	0.427
28	INTERORB BR	DKB	53	22.1	4.6	2.2	19.0	-	28.0	0.669	-0.139
29	NAS-DAC SUBT	NDS	53	10.7	2.0	1.4	7.0	-	13.0	-0.100	-0.398
30	SIMOTIC CHRD	WNB	53	9.1	4.5	2.1	5.4	-	15.3	0.668	0.162
31	SIMOTIC SUBT	SIS	53	3.9	1.1	1.0	1.5	-	6.6	0.338	0.302
32	MALR L (INF)	IML	53	32.7	7.4	2.7	26.0	-	38.0	0.169	-0.281
33	MALR L (MAX)	XML	53	49.4	7.3	2.7	43.0	-	55.0	-0.095	-0.079
34	MALAR SUBT	MLS	53	9.7	1.3	1.1	6.0	-	12.0	-0.762	1.416
35	CHEEK HEIGHT	WMH	53	21.1	4.0	2.0	17.0	-	27.0	0.470	0.450

TABLE A-2 CONTINUED

VARIABLE		CODE NAME	N	MEAN	VARIANCE	STD. DEV.	RANGE	SKEWNESS	KURTOSIS
36	SUPORB PROJ	SOS	53	5.3	1.0	1.0	3.0 - 8.0	0.377	0.045
37	GLABEL PROJ	GLS	53	2.4	0.9	0.9	1.0 - 5.0	0.364	-0.035
38	FOR MAGNUM L	FOL	53	36.2	6.2	2.5	31.0 - 42.0	0.049	-0.321
39	NAS-BREG CHD	FRC	53	106.2	15.3	3.9	96.0 - 113.0	-0.459	-0.199
40	NAS-BREG SUB	FRS	53	26.5	6.8	2.6	20.0 - 32.0	-0.412	-0.003
41	NAS-SUB FRAC	FRF	53	46.8	10.9	3.3	39.0 - 53.0	-0.259	-0.467
42	BREG-LAM CHD	PAC	53	105.2	32.1	5.7	95.0 - 118.0	0.289	-0.431
43	BREG-LAM SUB	PAS	53	23.3	8.6	2.9	17.0 - 29.0	-0.106	-0.398
44	BREG-SUB FRC	PAF	53	54.7	16.5	4.1	44.0 - 63.0	-0.154	-0.067
45	LAM-OPIS CHD	OCC	53	91.4	24.5	5.0	80.0 - 103.0	0.283	-0.007
46	LAM-OPIS SUB	OCS	53	27.9	12.6	3.5	20.0 - 39.0	0.671	0.933
47	LAM-SUB FRAC	OCF	53	45.9	34.4	5.9	36.0 - 58.0	0.323	-0.782
48	VERTEX RAD	VRR	53	116.3	9.0	3.0	108.0 - 122.0	-0.443	0.034
49	NASION RAD	NAR	53	89.7	9.1	3.0	83.0 - 97.0	-0.276	-0.103
50	SUBSPINAL RD	SSR	53	88.8	17.3	4.2	80.0 - 95.0	-0.207	-1.018
51	PROSTHION RD	PRR	53	93.8	21.4	4.6	82.0 - 104.0	-0.239	-0.278
52	DACRYON RAD	DKR	53	78.4	9.7	3.1	72.0 - 86.0	0.130	-0.338
53	ZYGORBIT RAD	ZOR	53	76.3	9.4	3.1	70.0 - 82.0	-0.135	-0.810
54	FRONTOMAL RD	FMR	53	73.3	7.2	2.7	66.0 - 79.0	-0.295	0.792
55	ECTOCONCH RD	EKR	53	67.9	6.6	2.6	60.0 - 73.0	-0.552	0.682
56	ZYGOMAX RAD	ZMR	53	68.0	10.2	3.2	60.0 - 74.0	-0.248	-0.080
57	M1 ALVEOL RD	AVR	53	74.8	17.4	4.2	64.0 - 84.0	-0.281	0.187
58	NASANG BA-PR	NAA	53	67.1	18.0	4.2	59.0 - 78.0	0.629	0.250
59	PROSAN NA-BA	PRA	53	72.2	13.8	3.7	64.0 - 81.0	-0.043	-0.542
60	BASANG NA-PR	BAA	53	40.6	9.4	3.1	33.0 - 50.0	0.541	1.383
61	NASANG BA-BR	NBA	53	77.1	14.3	3.8	68.0 - 85.0	-0.088	-0.104
62	BASANG NA-BR	BBA	53	56.4	10.9	3.3	50.0 - 63.0	-0.087	-0.694
63	ZYGOMAX ANG	SSA	53	128.0	31.7	5.6	111.0 - 139.0	-0.379	0.138
64	NAS-FRON ANG	NFA	53	141.2	23.0	4.8	127.0 - 151.0	-0.633	0.302
65	DACRYAL ANG	DKA	53	149.9	45.2	6.7	128.0 - 162.0	-0.711	0.668
66	NAS-DACR ANG	NDA	53	92.2	80.7	9.0	72.0 - 119.0	0.576	0.699
67	SIMOTIC ANG	SIA	53	99.1	135.2	11.6	77.0 - 132.0	0.669	0.601
68	FRONTAL ANG	FRA	53	126.4	16.8	4.1	116.0 - 136.0	0.312	0.087
69	PARIETAL ANG	PAA	53	132.2	17.6	4.2	125.0 - 141.0	0.107	-0.817
70	OCCIPITAL AN	OCA	53	117.0	30.9	5.6	103.0 - 129.0	-0.632	0.083

TABLE A-3. DESCRIPTIVE STATISTICS OF THE TOLAI MALE CRANIOMETRICS (IN MM)

VARIABLE		CODE NAME	N	MEAN	VARIANCE	STD. DEV.	RANGE			SKEWNESS	KURTOSIS
1	GLAB-OCC L	GOL	55	183.5	27.9	5.3	173.0	-	196.0	0.073	-0.564
2	NASIO-OCC L	NOL	55	179.0	25.2	5.0	168.0	-	191.0	0.040	-0.270
3	BAS-NAS L	BNL	55	101.5	13.2	3.6	95.0	-	110.0	0.385	-0.579
4	BAS-BREG HT	BBH	55	134.9	16.3	4.0	123.0	-	145.0	-0.209	0.184
5	MAX CRAN BR	XCB	55	130.4	15.3	3.9	121.0	-	139.0	-0.182	-0.369
6	MAX FRON BR	XFB	55	109.7	11.4	3.4	102.0	-	119.0	0.032	0.339
7	BISTEPH BR	STB	55	101.4	37.0	6.1	82.0	-	115.0	-0.424	1.026
8	BIZYGO BR	ZYB	55	136.0	9.6	3.1	128.0	-	144.0	0.254	-0.422
9	BIAURIC BR	AUB	55	119.9	13.6	3.7	112.0	-	128.0	0.009	-0.469
10	MIN CRAN BR	WCB	55	70.8	12.8	3.6	64.0	-	80.0	0.355	0.044
11	BIASTER BR	ASB	55	105.9	12.9	3.6	99.0	-	116.0	0.359	-0.031
12	BAS-PROSTH L	BPL	55	107.1	22.8	4.8	98.0	-	123.0	0.635	0.707
13	NAS-PROSTH H	NPH	55	66.1	16.1	4.0	57.0	-	75.0	-0.059	-0.538
14	NASAL HT	NLH	55	48.4	7.8	2.8	42.0	-	55.0	-0.185	0.077
15	ORBIT HT (L)	OBH	55	32.2	3.9	2.0	27.0	-	38.0	0.072	0.698
16	ORB BR (L)	OBB	55	41.2	2.9	1.7	38.0	-	46.0	0.397	0.254
17	BIJUGAL BR	JUB	55	118.6	11.8	3.4	110.0	-	126.0	-0.114	-0.055
18	NASAL BR	NLB	55	27.8	3.4	1.8	23.0	-	32.0	-0.073	-0.179
19	PALATE BR	MAB	55	66.0	8.7	2.9	61.0	-	75.0	0.709	0.548
20	MASTOID HT	MDH	55	28.8	10.3	3.2	19.0	-	36.0	-0.303	0.613
21	MASTOID WDTH	MDB	55	13.9	3.7	1.9	10.0	-	19.0	0.748	0.195
22	BIMAXILL BR	ZMB	55	97.6	17.0	4.1	90.0	-	110.0	0.784	0.865
23	ZYGOMAX SUBT	SSS	55	26.5	5.9	2.4	22.0	-	33.0	0.485	-0.305
24	BIFRONT BR	FMB	55	101.7	9.7	3.1	95.0	-	109.0	0.238	0.032
25	NAS-FRON SUB	NAS	55	16.8	3.7	1.9	13.0	-	21.0	-0.015	-0.513
26	BIORBITAL BR	EKB	55	101.2	8.8	3.0	95.0	-	108.0	0.177	0.108
27	DACRYON SUBT	DKS	55	9.8	3.2	1.8	4.0	-	13.0	-0.628	0.569
28	INTERORB BR	DKB	55	22.0	5.4	2.3	18.0	-	29.0	0.795	0.795
29	NAS-DAC SUBT	NDS	55	10.1	2.3	1.5	7.0	-	14.0	-0.060	-0.222
30	SIMOTIC CHRD	WNB	55	8.7	3.5	1.9	4.6	-	13.1	0.189	-0.250
31	SIMOTIC SUBT	SIS	55	3.5	0.8	0.9	1.6	-	6.4	0.714	1.068
32	MALR L (INF)	IML	55	41.3	12.2	3.5	30.0	-	48.0	-0.303	0.801
33	MALR L (MAX)	XML	55	56.5	11.1	3.3	50.0	-	65.0	0.207	-0.436
34	MALAR SUBT	MLS	55	11.5	3.4	1.8	8.0	-	17.0	0.399	0.143
35	CHEEK HEIGHT	WMH	55	22.9	5.4	2.3	19.0	-	28.0	0.307	-0.629

TABLE A-3 CONTINUED

VARIABLE	CODE NAME	N	MEAN	VARIANCE	STD. DEV.	RANGE	SKEWNESS	KURTOSIS
36 SUPORB PROJ	SOS	55	7.1	1.0	1.0	5.0 - 9.0	0.402	-0.472
37 GLABEL PROJ	GLS	55	4.7	1.9	1.4	2.0 - 9.0	0.590	1.168
38 FOR MAGNUM L	FOL	55	34.9	4.4	2.1	30.0 - 39.0	-0.254	-0.187
39 NAS-BREG CHD	FRC	55	108.7	16.2	4.0	101.0 - 118.0	0.281	-0.447
40 NAS-BREG SUB	FRS	55	24.0	4.5	2.1	21.0 - 28.0	0.202	-0.810
41 NAS-SUB FRAC	FRF	55	49.2	16.4	4.0	41.0 - 59.0	0.148	-0.581
42 BREG-LAM CHD	PAC	55	116.5	23.1	4.8	106.0 - 127.0	-0.270	-0.044
43 BREG-LAM SUB	PAS	55	25.9	7.8	2.8	20.0 - 33.0	0.110	-0.082
44 BREG-SUB FRC	PAF	55	58.3	19.7	4.4	45.0 - 68.0	-0.422	0.812
45 LAM-OPIS CHD	OCC	55	95.6	22.7	4.8	86.0 - 106.0	-0.110	-0.597
46 LAM-OPIS SUB	OCS	55	29.6	8.8	3.0	25.0 - 39.0	0.703	0.712
47 LAM-SUB FRAC	OCF	55	46.3	24.2	4.9	37.0 - 59.0	0.205	-0.463
48 VERTEX RAD	VRR	55	122.7	15.1	3.9	113.0 - 130.0	-0.028	-0.575
49 NASION RAD	NAR	55	95.5	10.1	3.2	89.0 - 102.0	0.124	-0.661
50 SUBSPINAL RD	SSR	55	102.8	13.2	3.6	95.0 - 109.0	-0.165	-0.751
51 PROSTHION RD	PRR	55	110.4	22.4	4.7	101.0 - 124.0	0.367	-0.110
52 DACRYON RAD	DKR	55	84.3	11.7	3.4	77.0 - 92.0	-0.029	-0.540
53 ZYGORBIT RAD	ZOR	55	83.8	11.9	3.4	75.0 - 93.0	0.110	0.291
54 FRONTOMAL RD	FMR	55	79.3	11.9	3.4	72.0 - 86.0	0.047	-0.489
55 ECTOCONCH RD	EKR	55	74.2	9.7	3.1	67.0 - 81.0	0.136	-0.379
56 ZYGOMAX RAD	ZMR	55	76.5	10.8	3.3	70.0 - 85.0	0.197	0.901
57 M1 ALVEOL RD	AVR	55	86.9	16.9	4.1	78.0 - 96.0	0.203	-0.155
58 NASANG BA-PR	NAA	55	76.3	10.8	3.3	70.0 - 84.0	0.231	-0.596
59 PROSAN NA-BA	PRA	55	67.0	8.1	2.9	61.0 - 74.0	0.033	-0.048
60 BASANG NA-PR	BAA	55	36.8	4.0	2.0	32.0 - 41.0	-0.130	-0.390
61 NASANG BA-BR	NBA	55	79.8	5.8	2.4	75.0 - 85.0	0.016	-0.641
62 BASANG NA-BR	BBA	55	52.5	4.0	2.0	49.0 - 58.0	0.373	0.033
63 ZYGOMAX ANG	SSA	55	122.9	18.5	4.3	112.0 - 131.0	-0.477	-0.226
64 NAS-FRON ANG	NFA	55	143.5	13.1	3.6	136.0 - 151.0	-0.043	-0.911
65 DACRYAL ANG	DKA	55	152.5	23.4	4.8	145.0 - 168.0	0.665	0.356
66 NAS-DACR ANG	NDA	55	95.3	122.7	11.1	75.0 - 122.0	0.504	-0.176
67 SIMOTIC ANG	SIA	55	102.6	276.6	16.6	68.0 - 133.0	-0.067	-1.025
68 FRONTAL ANG	FRA	55	132.0	10.4	3.2	127.0 - 138.0	0.151	-1.378
69 PARIETAL ANG	PAA	55	132.1	15.1	3.9	122.0 - 143.0	0.310	0.284
70 OCCIPITAL AN	OCA	55	116.2	16.9	4.1	106.0 - 124.0	-0.188	-0.547

TABLE A-4. DESCRIPTIVE STATISTICS OF THE TOLAI FEMALE CRANIOMETRICS (IN MM)

VARIABLE		CODE NAME	N	MEAN	VARIANCE	STD. DEV.	RANGE	SKEWNESS	KURTOSIS
1	GLAB-OCC L	GOL	55	174.7	27.7	5.3	164.0 - 188.0	0.138	-0.635
2	NASIO-OCC L	NOL	55	172.1	25.0	5.0	161.0 - 184.0	0.019	-0.587
3	BAS-NAS L	BNL	55	95.7	15.3	3.9	86.0 - 104.0	0.070	-0.008
4	BAS-BREG HT	BBH	55	127.3	13.7	3.7	119.0 - 137.0	0.163	0.136
5	MAX CRAN BR	XCB	55	128.1	16.4	4.1	120.0 - 139.0	0.386	-0.219
6	MAX FRON BR	XFB	55	106.8	16.0	4.0	97.0 - 119.0	0.200	0.517
7	BISTEPH BR	STB	55	100.7	36.2	6.0	82.0 - 117.0	-0.407	0.975
8	BIZYGO BR	ZYB	55	126.4	27.2	5.2	116.0 - 138.0	-0.048	-0.729
9	BIAURIC BR	AUB	55	115.2	19.7	4.4	106.0 - 126.0	0.001	-0.412
10	MIN CRAN BR	WCB	55	67.9	9.2	3.0	61.0 - 76.0	0.432	0.167
11	BIASTER BR	ASB	55	103.3	11.9	3.4	97.0 - 111.0	0.192	-0.683
12	BAS-PROSTH L	BPL	55	101.6	14.8	3.8	92.0 - 113.0	0.466	0.607
13	NAS-PROSTH H	NPH	55	62.8	13.5	3.7	54.0 - 70.0	-0.375	-0.577
14	NASAL HT	NLH	55	46.7	5.8	2.4	41.0 - 53.0	-0.015	-0.028
15	ORBIT HT (L)	OBH	55	32.3	3.0	1.7	28.0 - 36.0	-0.218	0.240
16	ORB BR (L)	OBB	55	39.1	2.7	1.6	36.0 - 42.0	-0.269	-0.783
17	BIJUGAL BR	JUB	55	110.9	14.9	3.9	104.0 - 122.0	0.608	0.358
18	NASAL BR	NLB	55	26.7	3.2	1.8	24.0 - 31.0	0.364	-0.534
19	PALATE BR	MAB	55	62.2	8.1	2.8	57.0 - 69.0	0.399	-0.400
20	MASTOID HT	MDH	55	26.1	9.2	3.0	20.0 - 31.0	-0.256	-0.888
21	MASTOID WDTH	MDB	55	11.7	2.4	1.6	8.0 - 15.0	-0.157	-0.248
22	BIMAXILL BR	ZMB	55	91.0	13.2	3.6	83.0 - 98.0	0.013	-0.609
23	ZYGOMAX SUBT	SSS	55	24.8	4.6	2.1	20.0 - 31.0	0.319	0.222
24	BIFRONT BR	FMB	55	96.3	9.9	3.2	89.0 - 103.0	0.089	-0.030
25	NAS-FRON SUB	NAS	55	15.5	3.9	2.0	11.0 - 21.0	0.338	0.191
26	BIORBITAL BR	EKB	55	96.3	10.5	3.2	89.0 - 104.0	0.214	-0.029
27	DACRYON SUBT	DKS	55	9.6	4.2	2.1	5.0 - 15.0	0.161	-0.312
28	INTERORB BR	DKB	55	21.2	3.5	1.9	18.0 - 26.0	0.337	-0.444
29	NAS-DAC SUBT	NDS	55	9.0	1.2	1.1	7.0 - 11.0	0.261	-0.690
30	SIMOTIC CHRD	WNB	55	8.4	3.9	2.0	4.6 - 12.6	0.071	-0.834
31	SIMOTIC SUBT	SIS	55	2.8	0.6	0.8	0.8 - 4.5	-0.274	-0.315
32	MALR L (INF)	IML	55	38.3	11.1	3.3	32.0 - 47.0	0.106	-0.162
33	MALR L (MAX)	XML	55	52.6	13.8	3.7	45.0 - 64.0	0.461	0.690
34	MALAR SUBT	MLS	55	10.9	1.8	1.3	8.0 - 14.0	0.261	-0.402
35	CHEEK HEIGHT	WMH	55	21.0	4.4	2.1	14.0 - 25.0	-0.270	1.329

TABLE A-4. CONTINUED

VARIABLE	CODE NAME	N	MEAN	VARIANCE	STD. DEV.	RANGE	SKEWNESS	KURTOSIS
36 SUPORB PROJ	SOS	55	6.0	0.9	0.9	4.0 - 8.0	-0.036	-0.632
37 GLABEL PROJ	GLS	55	3.1	1.0	1.0	2.0 - 6.0	0.638	-0.139
38 FOR MAGNUM L	FOL	55	33.2	5.4	2.3	29.0 - 39.0	0.491	-0.323
39 NAS-BREG CHD	FRC	55	103.0	15.7	4.0	95.0 - 113.0	0.254	-0.304
40 NAS-BREG SUB	FRS	55	23.4	5.7	2.4	19.0 - 28.0	0.154	-0.899
41 NAS-SUB FRAC	FRF	55	45.3	9.2	3.0	39.0 - 52.0	-0.138	-0.688
42 BREG-LAM CHD	PAC	55	112.5	24.7	5.0	102.0 - 124.0	0.326	-0.469
43 BREG-LAM SUB	PAS	55	25.1	5.2	2.3	20.0 - 30.0	-0.105	-0.627
44 BREG-SUB FRC	PAF	55	57.1	14.5	3.8	46.0 - 64.0	-0.603	0.416
45 LAM-OPIS CHD	OCC	55	93.4	10.8	3.3	87.0 - 102.0	0.638	-0.029
46 LAM-OPIS SUB	OCS	55	27.8	5.9	2.4	23.0 - 33.0	0.216	-0.078
47 LAM-SUB FRAC	OCF	55	44.5	10.0	3.2	38.0 - 54.0	0.294	0.319
48 VERTEX RAD	VRR	55	117.2	9.2	3.0	111.0 - 125.0	0.278	-0.365
49 NASION RAD	NAR	55	90.6	14.6	3.8	83.0 - 99.0	0.241	-0.046
50 SUBSPINAL RD	SSR	55	96.9	12.4	3.5	89.0 - 105.0	0.219	-0.135
51 PROSTHION RD	PRR	55	104.7	17.1	4.1	94.0 - 115.0	0.332	0.994
52 DACRYON RAD	DKR	55	80.3	12.2	3.5	73.0 - 88.0	0.174	-0.198
53 ZYGORBIT RAD	ZOR	55	79.9	11.8	3.4	73.0 - 88.0	0.192	0.019
54 FRONTOMAL RD	FMR	55	75.9	11.4	3.4	69.0 - 83.0	0.120	-0.410
55 ECTOCONCH RD	EKR	55	70.7	8.3	2.9	65.0 - 77.0	-0.079	-0.315
56 ZYGOMAX RAD	ZMR	55	72.5	12.3	3.5	65.0 - 81.0	-0.039	-0.095
57 M1 ALVEOL RD	AVR	55	81.4	14.0	3.7	73.0 - 90.0	0.074	0.200
58 NASANG BA-PR	NAA	55	76.6	9.7	3.1	71.0 - 83.0	0.131	-0.763
59 PROSAN NA-BA	PRA	55	66.5	9.0	3.0	60.0 - 73.0	0.223	-0.396
60 BASANG NA-PR	BAA	55	36.9	4.0	2.0	31.0 - 42.0	-0.283	1.008
61 NASANG BA-BR	NBA	55	79.6	5.1	2.3	75.0 - 84.0	-0.069	-0.768
62 BASANG NA-BR	BBA	55	52.7	3.9	2.0	49.0 - 58.0	0.125	-0.046
63 ZYGOMAX ANG	SSA	55	122.9	18.9	4.4	113.0 - 133.0	0.287	-0.189
64 NAS-FRON ANG	NFA	55	144.3	13.8	3.7	136.0 - 153.0	-0.208	-0.710
65 DACRYAL ANG	DKA	55	151.7	31.5	5.6	137.0 - 164.0	-0.198	-0.410
66 NAS-DACR ANG	NDA	55	99.5	60.7	7.8	79.0 - 115.0	-0.225	-0.422
67 SIMOTIC ANG	SIA	55	112.7	204.3	14.3	75.0 - 152.0	0.085	1.087
68 FRONTAL ANG	FRA	55	130.6	13.7	3.7	122.0 - 140.0	0.023	-0.196
69 PARIETAL ANG	PAA	55	131.8	9.5	3.1	126.0 - 140.0	0.316	-0.664
70 OCCIPITAL AN	OCA	55	118.4	17.5	4.2	108.0 - 126.0	-0.476	0.316

TABLE A-5. DESCRIPTIVE STATISTICS OF THE YAUYO MALE CRANIOMETRICS (IN MM)

VARIABLE		CODE NAME	N	MEAN	VARIANCE	STD. DEV.	RANGE	SKEWNESS	KURTOSIS
1	GLAB-OCC L	GOL	55	178.0	27.3	5.2	168.0 - 192.0	0.529	0.268
2	NASIO-OCC L	NOL	55	176.2	27.3	5.2	165.0 - 190.0	0.465	0.273
3	BAS-NAS L	BNL	55	96.0	12.4	3.5	88.0 - 105.0	0.289	-0.383
4	BAS-BREG HT	BBH	55	130.5	27.2	5.2	121.0 - 146.0	0.720	0.834
5	MAX CRAN BR	XCB	55	137.9	15.9	4.0	129.0 - 149.0	-0.004	-0.072
6	MAX FRON BR	XFB	55	115.2	19.1	4.4	107.0 - 126.0	0.083	-0.291
7	BISTEPH BR	STB	55	110.1	25.3	5.0	97.0 - 122.0	-0.154	0.042
8	BIZYGO BR	ZYB	55	134.9	18.3	4.3	124.0 - 149.0	0.481	1.150
9	BIAURIC BR	AUB	55	123.5	18.8	4.3	114.0 - 134.0	0.198	-0.364
10	MIN CRAN BR	WCB	55	71.6	10.3	3.2	66.0 - 81.0	0.197	-0.047
11	BIASTER BR	ASB	55	108.2	19.1	4.4	98.0 - 116.0	-0.231	-0.653
12	BAS-PROSTH L	BPL	55	94.3	17.5	4.2	85.0 - 104.0	-0.094	-0.165
13	NAS-PROSTH H	NPH	55	67.8	12.9	3.6	60.0 - 76.0	0.203	-0.730
14	NASAL HT	NLH	55	50.3	5.0	2.2	46.0 - 55.0	0.141	-0.788
15	ORBIT HT (L)	OBH	55	34.3	2.2	1.5	31.0 - 37.0	-0.409	-0.680
16	ORB BR (L)	OBB	55	38.3	2.0	1.4	36.0 - 41.0	0.212	-0.751
17	BIJUGAL BR	JUB	55	116.1	14.1	3.7	109.0 - 126.0	0.497	0.003
18	NASAL BR	NLB	55	25.2	3.2	1.8	20.0 - 30.0	-0.025	0.737
19	PALATE BR	MAB	55	64.6	11.1	3.3	59.0 - 72.0	0.320	-0.627
20	MASTOID HT	MDH	55	30.0	9.9	3.1	23.0 - 38.0	0.095	0.077
21	MASTOID WDTH	MDB	55	12.6	2.7	1.7	10.0 - 17.0	0.781	0.326
22	BIMAXILL BR	ZMB	55	96.9	17.5	4.2	89.0 - 109.0	0.572	0.089
23	ZYGOMAX SUBT	SSS	55	22.6	4.6	2.1	18.0 - 29.0	0.622	0.617
24	BIFRONT BR	FMB	55	96.1	9.9	3.1	90.0 - 105.0	0.353	0.121
25	NAS-FRON SUB	NAS	55	15.9	4.3	2.1	12.0 - 20.0	-0.014	-0.916
26	BIORBITAL BR	EKB	55	95.5	9.2	3.0	90.0 - 104.0	0.558	0.266
27	DACRYON SUBT	DKS	55	8.9	3.3	1.8	5.0 - 12.0	-0.115	-0.669
28	INTERORB BR	DKB	55	21.1	3.9	2.0	18.0 - 27.0	0.961	1.323
29	NAS-DAC SUBT	NDS	55	10.4	1.5	1.2	8.0 - 14.0	0.112	0.245
30	SIMOTIC CHRD	WNB	55	9.1	2.0	1.4	6.1 - 12.0	-0.027	-0.329
31	SIMOTIC SUBT	SIS	55	4.4	1.0	1.0	2.4 - 6.2	-0.095	-0.733
32	MALR L (INF)	IML	55	35.5	10.1	3.2	30.0 - 42.0	0.149	-0.449
33	MALR L (MAX)	XML	55	52.6	10.0	3.2	45.0 - 59.0	0.001	-0.546
34	MALAR SUBT	MLS	55	10.4	2.3	1.5	7.0 - 14.0	-0.150	-0.137
35	CHEEK HEIGHT	WMH	55	24.5	4.0	2.0	18.0 - 28.0	-0.769	0.934

TABLE A-5. CONTINUED

VARIABLE	CODE NAME	N	MEAN	VARIANCE	STD. DEV.	RANGE	SKEWNESS	KURTOSIS
36 SUPORB PROJ	SOS	55	7.1	1.0	1.0	5.0 - 9.0	0.402	-0.472
37 GLABEL PROJ	GLS	55	4.7	1.9	1.4	2.0 - 9.0	0.590	1.168
38 FOR MAGNUM L	FOL	55	34.9	4.4	2.1	30.0 - 39.0	-0.254	-0.187
39 NAS-BREG CHD	FRC	55	108.7	16.2	4.0	101.0 - 118.0	0.281	-0.447
40 NAS-BREG SUB	FRS	55	24.0	4.5	2.1	21.0 - 28.0	0.202	-0.910
41 NAS-SUB FRAC	FRF	55	49.2	16.4	4.0	41.0 - 58.0	0.148	-0.581
42 BREG-LAM CHD	PAC	55	116.5	23.1	4.8	106.0 - 127.0	-0.270	-0.044
43 BREG-LAM SUB	PAS	55	25.9	7.8	2.8	20.0 - 33.0	0.110	-0.082
44 BREG-SUB FRC	PAF	55	58.3	19.7	4.4	45.0 - 68.0	-0.422	0.812
45 LAM-OPIS CHD	OCC	55	95.6	22.7	4.8	86.0 - 106.0	-0.110	-0.587
46 LAM-OPIS SUB	OCS	55	29.6	8.8	3.0	25.0 - 39.0	0.703	0.712
47 LAM-SUB FRAC	OCF	55	46.3	24.2	4.9	37.0 - 59.0	0.205	-0.463
48 VERTEX RAD	VRR	55	122.7	15.1	3.9	113.0 - 130.0	-0.028	-0.575
49 NASION RAD	NAR	55	95.5	10.1	3.2	89.0 - 102.0	0.124	-0.661
50 SUBSPINAL RD	SSR	55	102.8	13.2	3.6	95.0 - 109.0	-0.165	-0.751
51 PROSTHION RD	PRR	55	110.4	22.4	4.7	101.0 - 124.0	0.367	-0.110
52 DACRYON RAD	DKR	55	84.3	11.7	3.4	77.0 - 92.0	-0.029	-0.540
53 ZYGORBIT RAD	ZOR	55	83.8	11.9	3.4	75.0 - 93.0	0.110	0.291
54 FRONTOMAL RD	FMR	55	79.3	11.9	3.4	72.0 - 86.0	0.047	-0.499
55 ECTOCONCH RD	EKR	55	74.2	9.7	3.1	67.0 - 81.0	0.136	-0.379
56 ZYGOMAX RAD	ZMR	55	76.5	10.8	3.3	70.0 - 85.0	0.197	0.031
57 M1 ALVEOL RD	AVR	55	86.9	16.9	4.1	78.0 - 96.0	0.203	-0.155
58 NASANG BA-PR	NAA	55	76.3	10.8	3.3	70.0 - 84.0	0.231	-0.596
59 PROSAN NA-BA	PRA	55	67.0	8.1	2.9	61.0 - 74.0	0.033	-0.348
60 BASANG NA-PR	BAA	55	36.8	4.0	2.0	32.0 - 41.0	-0.130	-0.380
61 NASANG BA-BR	NBA	55	79.8	5.8	2.4	75.0 - 85.0	0.016	-0.641
62 BASANG NA-BR	BBA	55	52.5	4.0	2.0	49.0 - 58.0	0.373	0.033
63 ZYGOMAX ANG	SSA	55	122.9	18.5	4.3	112.0 - 131.0	-0.477	-0.226
64 NAS-FRON ANG	NFA	55	143.5	13.1	3.6	136.0 - 151.0	-0.043	-0.911
65 DACRYAL ANG	DKA	55	152.5	23.4	4.8	145.0 - 168.0	0.665	0.366
66 NAS-DACR ANG	NDA	55	95.3	122.7	11.1	75.0 - 122.0	0.504	-0.176
67 SIMOTIC ANG	SIA	55	102.6	276.6	16.6	68.0 - 133.0	-0.067	-1.925
68 FRONTAL ANG	FRA	55	132.0	10.4	3.2	127.0 - 138.0	0.151	-1.378
69 PARIETAL ANG	PAA	55	132.1	15.1	3.9	122.0 - 143.0	0.310	0.284
70 OCCIPITAL AN	OCA	55	116.2	16.9	4.1	106.0 - 124.0	-0.188	-0.547

TABLE A-6. DESCRIPTIVE STATISTICS OF THE YAUYO FEMALE CRANIOMETRICS (IN MM)

VARIABLE	CODE NAME	N	MEAN	VARIANCE	STD. DEV.	RANGE	SKEWNESS	KURTOSIS
1 GLAB-OCC L	GOL	54	169.0	27.6	5.3	157.0 - 178.0	-0.334	-0.584
2 NASIO-OCC L	NOL	54	168.2	27.3	5.2	156.0 - 177.0	-0.300	-0.659
3 BAS-NAS L	BNL	54	90.7	13.4	3.7	83.0 - 99.0	0.420	-0.066
4 BAS-BREG HT	BBH	54	125.0	16.4	4.1	117.0 - 134.0	0.002	-0.602
5 MAX CRAN BR	XCB	54	135.1	17.7	4.2	126.0 - 145.0	-0.177	-0.628
6 MAX FRON BR	XFB	54	112.2	17.4	4.2	105.0 - 124.0	0.690	0.153
7 BISTEPH BR	STB	54	109.3	25.2	5.0	98.0 - 120.0	0.287	-0.393
8 BIZYGO BR	ZYB	54	125.7	16.4	4.1	117.0 - 135.0	0.111	-0.289
9 BIAURIC BR	AUB	54	117.6	18.2	4.3	106.0 - 126.0	-0.279	-0.169
10 MIN CRAN BR	WCB	54	67.7	10.9	3.3	61.0 - 76.0	-0.005	-0.445
11 BIASTER BR	ASB	54	105.3	17.1	4.1	97.0 - 115.0	0.197	-0.391
12 BAS-PROSTH L	BPL	54	88.9	15.9	4.0	80.0 - 98.0	0.272	-0.398
13 NAS-PROSTH H	NPH	54	63.7	13.7	3.7	56.0 - 73.0	0.402	0.177
14 NASAL HT	NLH	54	47.7	6.1	2.5	42.0 - 54.0	-0.114	-0.185
15 ORBIT HT (L)	OBH	54	34.2	2.0	1.4	31.0 - 38.0	0.244	-0.074
16 ORB BR (L)	OBB	54	36.9	1.5	1.2	34.0 - 40.0	0.425	-0.203
17 BIJUGAL BR	JUB	54	108.7	12.4	3.5	102.0 - 115.0	-0.094	-1.001
18 NASAL BR	NLB	54	23.9	2.6	1.6	21.0 - 28.0	0.256	-0.361
19 PALATE BR	MAB	54	61.1	9.3	3.0	55.0 - 68.0	0.098	-0.560
20 MASTOID HT	MDH	54	26.4	8.5	2.9	21.0 - 34.0	0.478	-0.029
21 MASTOID WDTH	MDB	54	10.8	2.1	1.4	8.0 - 16.0	0.696	1.722
22 BIMAXILL BR	ZMB	54	91.8	15.9	4.0	82.0 - 99.0	-0.297	-0.367
23 ZYGOMAX SUBT	SSS	54	21.8	4.5	2.1	17.0 - 26.0	-0.042	-0.587
24 BIFRONT BR	FMB	54	91.2	7.8	2.8	84.0 - 97.0	-0.027	-0.455
25 NAS-FRON SUB	NAS	54	14.4	3.8	2.0	10.0 - 19.0	0.036	0.044
26 BIORBITAL BR	EKB	54	90.9	7.6	2.8	84.0 - 96.0	0.024	-0.485
27 DACRYON SUBT	DKS	54	8.5	2.7	1.6	5.0 - 12.0	0.185	-0.133
28 INTERORB BR	DKB	54	19.5	3.4	1.9	16.0 - 26.0	0.907	1.467
29 NAS-DAC SUBT	NDS	54	9.6	1.4	1.2	7.0 - 12.0	-0.345	-0.444
30 SIMOTIC CHRD	WNB	54	8.6	2.0	1.4	5.4 - 11.8	0.121	-0.338
31 SIMOTIC SUBT	SIS	54	3.7	0.5	0.7	2.4 - 5.4	0.365	-0.479
32 MALR L (INF)	IML	54	31.9	9.6	3.1	26.0 - 41.0	0.353	0.304
33 MALR L (MAX)	XML	54	48.0	10.6	3.3	42.0 - 57.0	0.393	-0.058
34 MALAR SUBT	MLS	54	9.6	2.1	1.4	7.0 - 14.0	0.277	0.297
35 CHEEK HEIGHT	WMH	54	22.0	4.8	2.2	18.0 - 26.0	-0.355	-0.806

TABLE A-6. CONTINUED

VARIABLE		CODE NAME	N	MEAN	VARIANCE	STD. DEV.	RANGE			SKEWNESS	KURTOSIS
36	SUPORB PROJ	SOS	54	4.6	1.0	1.0	3.0	-	7.0	0.383	-0.599
37	GLABEL PROJ	GLS	53	2.0	0.6	0.8	1.0	-	4.0	0.661	0.393
38	FOR MAGNUM L	FOL	54	33.9	3.9	2.0	30.0	-	39.0	0.213	0.630
39	NAS-BREG CHD	FRC	54	105.1	16.1	4.0	96.0	-	113.0	-0.011	-0.614
40	NAS-BREG SUB	FRS	54	23.3	5.0	2.2	20.0	-	28.0	0.377	-0.968
41	NAS-SUB FRAC	FRF	54	45.1	8.1	2.8	39.0	-	52.0	0.128	-0.471
42	BREG-LAM CHD	PAC	54	104.1	37.6	6.1	90.0	-	115.0	-0.286	-0.574
43	BREG-LAM SUB	PAS	54	22.6	10.0	3.2	16.0	-	29.0	-0.027	-0.409
44	BREG-SUB FRC	PAF	54	51.7	19.2	4.3	40.0	-	61.0	-0.421	0.016
45	LAM-OPIS CHD	OCC	54	95.5	38.9	6.2	81.0	-	108.0	-0.273	-0.299
46	LAM-OPIS SUB	OCS	54	29.5	12.6	3.5	19.0	-	37.0	-0.188	0.196
47	LAM-SUB FRAC	OCF	54	45.9	21.2	4.6	39.0	-	62.0	1.067	1.999
48	VERTEX RAD	VRR	54	117.9	13.0	3.6	109.0	-	126.0	-0.477	-0.325
49	NASION RAD	NAR	54	84.5	12.0	3.5	78.0	-	92.0	0.280	-0.459
50	SUBSPINAL RD	SSR	54	85.3	13.5	3.7	76.0	-	93.0	-0.171	-0.275
51	PROSTHION RD	PRR	54	91.1	16.7	4.1	81.0	-	100.0	-0.146	-0.271
52	DACRYON RAD	DKR	54	74.1	9.1	3.0	67.0	-	81.0	-0.160	-0.491
53	ZYGORBIT RAD	ZOR	54	70.6	10.4	3.2	61.0	-	76.0	-0.532	0.358
54	FRONTOMAL RD	FMR	54	70.6	7.0	2.7	63.0	-	77.0	-0.307	0.363
55	ECTOCONCH RD	EKR	54	65.1	5.7	2.4	57.0	-	69.0	-0.828	1.038
56	ZYGOMAX RAD	ZMR	54	63.6	13.9	3.7	54.0	-	72.0	-0.255	0.227
57	M1 ALVEOL RD	AVR	54	70.8	13.6	3.7	61.0	-	79.0	-0.083	0.527
58	NASANG BA-PR	NAA	54	67.7	9.5	3.1	60.0	-	75.0	-0.278	0.396
59	PROSAN NA-BA	PRA	54	70.8	8.8	3.0	66.0	-	79.0	0.614	0.282
60	BASANG NA-PR	BAA	54	41.4	5.2	2.3	36.0	-	47.0	-0.071	-0.000
61	NASANG BA-BR	NBA	54	79.0	6.1	2.5	73.0	-	84.0	-0.295	-0.217
62	BASANG NA-BR	BBA	54	55.6	4.8	2.2	51.0	-	59.0	-0.379	-0.676
63	ZYGOMAX ANG	SSA	54	129.1	18.6	4.3	120.0	-	139.0	0.053	-0.568
64	NAS-FRON ANG	NFA	54	145.1	17.2	4.1	136.0	-	155.0	0.048	-0.117
65	DACRYAL ANG	DKA	54	153.3	25.6	5.1	142.0	-	164.0	-0.109	-0.293
66	NAS-DACR ANG	NDA	54	91.3	69.5	8.3	77.0	-	111.0	0.581	-0.195
67	SIMOTIC ANG	SIA	54	98.5	146.0	12.1	75.0	-	127.0	0.123	-0.517
68	FRONTAL ANG	FRA	54	131.3	12.8	3.6	122.0	-	137.0	-0.605	-0.548
69	PARIETAL ANG	PAA	54	133.0	19.5	4.4	123.0	-	144.0	-0.074	-0.270
70	OCCIPITAL AN	OCA	54	116.5	16.3	4.0	108.0	-	131.0	0.743	1.962

TABLE A-7. DESCRIPTIVE STATISTICS OF THE SULLY MALE CRANIOMETRICS (IN MM)

VARIABLE		CODE NAME	N	MEAN	VARIANCE	STD. DEV.	RANGE	SKEWNESS	KURTOSIS
1	GLAB-OCC L	GOL	42	179.5	33.8	5.8	167.0 - 190.0	0.317	-0.903
2	NASIO-OCC L	NOL	42	177.7	33.0	5.7	166.0 - 190.0	0.421	-0.816
3	BAS-NAS L	BNL	42	102.8	9.6	3.1	97.0 - 110.0	0.063	-0.286
4	BAS-BREG HT	BBH	42	133.4	17.2	4.1	122.0 - 141.0	-0.222	-0.086
5	MAX CRAN BR	XCB	42	141.5	28.4	5.3	128.0 - 153.0	-0.146	0.044
6	MAX FRON BR	XFB	42	116.4	21.8	4.7	103.0 - 128.0	-0.104	0.638
7	BISTEPH BR	STB	42	108.4	52.9	7.3	91.0 - 125.0	-0.229	-0.129
8	BIZYGO BR	ZYB	42	140.9	29.1	5.4	126.0 - 151.0	-0.255	-0.039
9	BIAURIC BR	AUB	42	131.3	24.2	4.9	120.0 - 143.0	0.239	0.094
10	MIN CRAN BR	WCB	42	74.4	14.1	3.8	67.0 - 83.0	0.236	-0.183
11	BIASTER BR	ASB	42	109.0	26.7	5.2	95.0 - 120.0	0.133	0.165
12	BAS-PROSTH L	BPL	42	98.6	15.5	3.9	89.0 - 106.0	-0.118	-0.196
13	NAS-PROSTH H	NPH	42	71.7	15.0	3.9	63.0 - 80.0	0.080	-0.298
14	NASAL HT	NLH	42	54.5	6.4	2.5	47.0 - 61.0	-0.274	1.195
15	ORBIT HT (L)	OBH	42	35.0	3.5	1.9	29.0 - 38.0	-0.850	0.758
16	ORB BR (L)	OBB	42	40.5	1.3	1.2	38.0 - 43.0	0.173	-0.420
17	BIJUGAL BR	JUB	42	122.3	21.1	4.6	112.0 - 129.0	-0.660	-0.442
18	NASAL BR	NLB	42	27.1	3.0	1.7	24.0 - 31.0	0.163	-0.504
19	PALATE BR	MAB	42	66.9	8.3	2.9	61.0 - 74.0	0.306	-0.128
20	MASTOID HT	MDH	42	28.2	7.4	2.7	23.0 - 34.0	0.371	-0.333
21	MASTOID WDTH	MDB	42	12.9	2.8	1.7	9.0 - 18.0	0.322	0.741
22	BIMAXILL BR	ZMB	42	101.2	18.3	4.3	89.0 - 107.0	-0.725	0.173
23	ZYGOMAX SUBT	SSS	42	25.9	6.4	2.5	19.0 - 30.0	-0.612	0.691
24	BIFRONT BR	FMB	42	99.0	9.9	3.1	92.0 - 105.0	-0.107	-0.341
25	NAS-FRON SUB	NAS	42	17.5	4.2	2.0	14.0 - 22.0	0.262	-0.303
26	BIORBITAL BR	EKB	42	99.2	9.8	3.1	92.0 - 106.0	-0.113	-0.140
27	DACRYON SUBT	DKS	42	10.4	3.6	1.9	7.0 - 14.0	0.039	-0.735
28	INTERORB BR	DKB	42	21.1	4.3	2.1	17.0 - 26.0	0.396	0.459
29	NAS-DAC SUBT	NDS	42	10.6	1.5	1.2	8.0 - 14.0	0.598	0.443
30	SIMOTIC CHRD	WNB	42	8.6	3.3	1.8	4.7 - 14.3	0.924	1.352
31	SIMOTIC SUBT	SIS	42	4.2	1.1	1.1	1.9 - 6.2	-0.049	-0.569
32	MALR L (INF)	IML	42	38.3	6.4	2.5	34.0 - 44.0	0.166	-0.425
33	MALR L (MAX)	XML	42	55.9	8.1	2.8	50.0 - 62.0	0.047	-0.486
34	MALAR SUBT	MLS	42	11.6	1.9	1.4	9.0 - 14.0	-0.342	-0.304
35	CHEEK HEIGHT	WMH	42	24.4	3.9	2.0	20.0 - 28.0	-0.017	-0.314

TABLE A-7 CONTINUED

VARIABLE		CODE NAME	N	MEAN	VARIANCE	STD. DEV.	RANGE			SKEWNESS	KURTOSIS
36	SUPORB PROJ	SOS	42	6.5	1.2	1.1	4.0	-	9.0	-0.050	0.020
37	GLABEL PROJ	GLS	42	3.5	1.1	1.1	1.0	-	5.0	-0.060	-0.741
38	FOR MAGNUM L	FOL	42	37.9	5.4	2.3	33.0	-	42.0	-0.191	-0.644
39	NAS-BREG CHD	FRC	42	109.3	16.5	4.1	100.0	-	117.0	-0.199	-0.547
40	NAS-BREG SUB	FRS	42	21.3	6.6	2.6	16.0	-	29.0	0.232	0.494
41	NAS-SUB FRAC	FRF	42	50.7	20.9	4.6	42.0	-	60.0	-0.047	-0.998
42	BREG-LAM CHD	PAC	42	108.9	15.0	3.9	101.0	-	116.0	-0.354	-0.894
43	BREG-LAM SUB	PAS	42	24.1	5.0	2.2	19.0	-	29.0	-0.375	0.993
44	BREG-SUB FRC	PAF	42	54.7	20.3	4.5	40.0	-	61.0	-0.394	1.194
45	LAM-OPIS CHD	OCC	42	95.1	34.3	5.9	87.0	-	113.0	1.150	1.520
46	LAM-OPIS SUB	OCS	42	27.5	14.5	3.8	22.0	-	38.0	0.748	0.581
47	LAM-SUB FRAC	OCF	42	45.5	27.7	5.3	37.0	-	62.0	1.073	1.403
48	VERTEX RAD	VRR	42	120.9	15.1	3.9	113.0	-	130.0	0.364	-0.243
49	NASION RAD	NAR	42	97.1	11.3	3.4	91.0	-	104.0	0.224	-0.765
50	SUBSPINAL RD	SSR	42	99.0	15.0	3.9	91.0	-	106.0	-0.292	-0.675
51	PROSTHION RD	PRR	42	104.0	15.5	3.9	94.0	-	111.0	-0.330	-0.369
52	DACRYON RAD	DKR	42	84.9	11.8	3.4	72.0	-	92.0	-1.011	3.135
53	ZYGORBIT RAD	ZOR	42	81.0	10.0	3.2	72.0	-	87.0	-0.444	0.997
54	FRONTOMAL RD	FMR	42	80.4	9.3	3.1	72.0	-	86.0	-0.370	0.404
55	ECTOCONCH RD	EKR	42	74.3	8.4	2.9	66.0	-	80.0	-0.612	0.430
56	ZYGOMAX RAD	ZMR	42	74.1	9.0	3.0	67.0	-	81.0	-0.129	-0.161
57	ML ALVEOL RD	AVR	42	83.6	12.7	3.6	75.0	-	91.0	-0.362	-0.255
58	NASANG BA-PR	NAA	42	66.0	8.4	2.9	60.0	-	72.0	-0.049	-0.697
59	PROSAN NA-BA	PRA	42	72.3	7.7	2.8	68.0	-	78.0	0.373	-0.927
60	BASANG NA-PR	BAA	42	41.6	4.7	2.2	38.0	-	48.0	0.370	0.486
61	NASANG BA-BR	NBA	42	77.9	4.6	2.1	74.0	-	84.0	0.412	0.202
62	BASANG NA-BR	BBA	42	53.3	3.8	1.9	50.0	-	58.0	0.221	-0.440
63	ZYGOMAX ANG	SSA	42	125.9	19.2	4.4	119.0	-	138.0	0.817	0.727
64	NAS-FRON ANG	NFA	42	141.0	15.6	3.9	133.0	-	148.0	-0.263	-0.905
65	DACRYAL ANG	DKA	42	150.4	26.4	5.1	139.0	-	160.0	-0.156	-0.699
66	NAS-DACR ANG	NDA	42	89.8	56.2	7.5	75.0	-	105.0	0.095	-0.495
67	SIMOTIC ANG	SIA	42	91.0	230.8	15.2	63.0	-	127.0	0.150	-0.638
68	FRONTAL ANG	FRA	42	137.1	16.4	4.0	126.0	-	145.0	-0.110	-0.132
69	PARIETAL ANG	PAA	42	132.0	14.6	3.8	125.0	-	140.0	0.387	-0.393
70	OCCIPITAL AN	OCA	42	119.8	31.7	5.6	104.0	-	132.0	-0.310	0.323

TABLE A-8. DESCRIPTIVE STATISTICS OF THE SULLY FEMALE CRANIOMETIRCS (IN MM)

VARIABLE		CODE NAME	N	MEAN	VARIANCE	STD. DEV.	RANGE	SKEWNESS	KURTOSIS
1	GLAB-OCC L	GOL	27	171.1	36.7	6.1	162.0 - 186.0	0.430	-0.279
2	NASIO-OCC L	NOL	27	170.2	37.7	6.1	161.0 - 185.0	0.701	0.044
3	BAS-NAS L	BNL	27	97.5	13.3	3.7	90.0 - 104.0	0.274	-0.705
4	BAS-BREG HT	BBH	27	126.8	22.8	4.8	118.0 - 137.0	0.359	-0.638
5	MAX CRAN BR	XCB	27	136.5	24.7	5.0	126.0 - 147.0	-0.176	-0.376
6	MAX FRON BR	XFB	27	112.8	18.0	4.2	105.0 - 122.0	-0.063	-0.496
7	BISTEPH BR	STB	27	107.9	24.7	5.0	100.0 - 117.0	0.039	-1.022
8	BIZYGO BR	ZYB	27	130.7	19.7	4.4	122.0 - 143.0	0.573	0.646
9	BIAURIC BR	AUB	27	123.9	20.3	4.5	118.0 - 134.0	0.515	-0.561
10	MIN CRAN BR	WCB	27	71.3	11.8	3.4	64.0 - 79.0	0.251	-0.165
11	BIASTER BR	ASB	27	105.4	32.9	5.7	95.0 - 118.0	0.449	-0.212
12	BAS-PROSTH L	BPL	27	95.1	18.1	4.3	87.0 - 104.0	0.124	-0.358
13	NAS-PROSTH H	NPH	27	67.6	14.5	3.8	60.0 - 76.0	0.134	-0.398
14	NASAL HT	NLH	27	50.5	4.4	2.1	46.0 - 55.0	-0.077	-0.226
15	ORBIT HT (L)	OBH	27	34.6	3.0	1.7	32.0 - 38.0	0.093	-1.100
16	ORB BR (L)	OBB	27	39.2	1.7	1.3	37.0 - 42.0	-0.001	-0.608
17	BIJUGAL BR	JUB	27	115.0	11.4	3.4	108.0 - 124.0	0.233	1.045
18	NASAL BR	NLB	27	25.8	2.6	1.6	23.0 - 30.0	0.638	0.275
19	PALATE BR	MAB	27	62.1	8.1	2.9	55.0 - 68.0	-0.269	-0.971
20	MASTOID HT	MDH	27	24.9	6.1	2.5	19.0 - 29.0	-0.557	-0.164
21	MASTOID WDTH	MDB	27	11.1	1.9	1.4	8.0 - 14.0	-0.028	-0.475
22	BIMAXILL BR	ZMB	27	94.8	11.0	3.3	88.0 - 101.0	-0.086	-0.301
23	ZYGOMAX SUBT	SSS	27	23.6	6.5	2.6	19.0 - 30.0	0.254	-0.904
24	BIFRONT BR	FMB	27	94.8	8.1	2.8	89.0 - 100.0	-0.322	-0.641
25	NAS-FRON SUB	NAS	27	16.3	4.9	2.2	11.0 - 22.0	-0.058	0.895
26	BIORBITAL BR	EKB	27	96.0	8.0	2.8	91.0 - 101.0	-0.161	-0.720
27	DACRYON SUBT	DKS	27	10.3	4.5	2.1	6.0 - 15.0	0.464	0.199
28	INTERORB BR	OKB	27	20.1	3.3	1.8	17.0 - 24.0	0.526	-0.278
29	NAS-DAC SUBT	NDS	27	9.5	1.6	1.3	7.0 - 12.0	-0.181	-0.593
30	SIMOTIC CHRD	WNB	27	8.6	4.2	2.1	2.7 - 11.9	-1.043	1.325
31	SIMOTIC SUBT	SIS	27	3.5	1.3	1.1	0.6 - 5.3	-0.565	-0.032
32	MALR L (INF)	IML	27	34.9	7.1	2.7	28.0 - 40.0	-0.456	0.210
33	MALR L (MAX)	XML	27	50.7	10.2	3.2	45.0 - 57.0	-0.075	-0.845
34	MALAR SUBT	MLS	27	10.7	1.1	1.1	8.0 - 12.0	-0.546	-0.168
35	CHEEK HEIGHT	WMH	27	22.3	3.8	2.0	19.0 - 26.0	0.197	-0.634

TABLE A-8 CONTINUED

VARIABLE		CODE NAME	N	MEAN	VARIANCE	STD. DEV.	RANGE	SKEWNESS	KURTOSIS
36	SUPORB PROJ	SOS	27	4.7	0.8	0.9	3.0 - 6.0	-0.109	-0.822
37	GLABEL PROJ	GLS	27	2.1	0.8	0.9	1.0 - 5.0	1.110	2.218
38	FOR MAGNUM L	FOL	27	35.4	3.7	1.9	32.0 - 40.0	0.070	-0.262
39	NAS-BREG CHD	FRC	27	105.6	24.9	5.0	97.0 - 117.0	0.238	-0.362
40	NAS-BREG SUB	FRS	27	23.4	7.3	2.7	19.0 - 29.0	0.216	-0.767
41	NAS-SUB FRAC	FRF	27	46.8	18.6	4.3	39.0 - 57.0	0.302	-0.090
42	BREG-LAM CHD	PAC	27	104.1	15.5	3.9	96.0 - 114.0	0.234	0.185
43	BREG-LAM SUB	PAS	27	22.6	6.9	2.6	17.0 - 27.0	-0.305	-0.415
44	BREG-SUB FRC	PAF	27	53.4	18.0	4.2	43.0 - 61.0	-0.595	0.011
45	LAM-OPIS CHD	OCC	27	91.0	34.8	5.9	82.0 - 102.0	0.522	-0.901
46	LAM-OPIS SUB	OCS	27	26.6	17.4	4.2	21.0 - 35.0	0.395	-0.912
47	LAM-SUB FRAC	OCF	27	44.1	31.4	5.6	33.0 - 58.0	0.190	0.162
48	VERTEX RAD	VRR	27	115.9	13.0	3.6	109.0 - 123.0	-0.115	-0.685
49	NASION RAD	NAR	27	91.9	17.5	4.2	86.0 - 106.0	1.473	2.983
50	SUBSPINAL RD	SSR	27	93.1	15.7	4.0	87.0 - 106.0	1.082	2.151
51	PROSTHION RD	PRR	27	98.9	20.2	4.5	90.0 - 113.0	0.736	2.020
52	DACRYON RAD	DKR	27	81.3	16.1	4.0	76.0 - 94.0	1.305	1.922
53	ZYGORBIT RAD	ZOR	27	77.6	10.8	3.3	72.0 - 88.0	1.093	1.855
54	FRONTOMAL RD	FMR	27	76.5	10.0	3.2	71.0 - 86.0	1.022	1.504
55	ECTOCONCH RD	EKR	27	70.9	6.6	2.6	67.0 - 80.0	1.682	4.217
56	ZYGOMAX RAD	ZMR	27	70.4	7.8	2.8	66.0 - 78.0	0.704	0.320
57	M1 ALVEOL RD	AVR	27	78.4	12.2	3.5	72.0 - 90.0	1.102	2.779
58	NASANG BA-PR	NAA	27	67.6	9.3	3.1	63.0 - 73.0	0.111	-0.997
59	PROSAN NA-BA	PRA	27	71.4	14.5	3.8	65.0 - 80.0	0.435	-0.518
60	BASANG NA-PR	BAA	27	41.0	6.2	2.5	36.0 - 48.0	0.408	0.833
61	NASANG BA-BR	NBA	27	77.2	11.8	3.4	68.0 - 85.0	-0.056	0.663
62	BASANG NA-BR	BBA	27	54.3	11.2	3.3	48.0 - 62.0	0.013	-0.347
63	ZYGOMAX ANG	SSA	27	126.9	27.8	5.3	117.0 - 136.0	0.007	-0.833
64	NAS-FRON ANG	NFA	27	142.1	22.0	4.7	131.0 - 153.0	0.277	0.426
65	DACRYAL ANG	DKA	27	149.6	35.6	6.0	137.0 - 161.0	-0.279	-0.436
66	NAS-DACR ANG	NDA	27	93.7	96.1	9.8	79.0 - 115.0	0.361	-0.665
67	SIMOTIC ANG	SIA	27	103.6	209.1	14.5	75.0 - 132.0	0.220	-0.544
68	FRONTAL ANG	FRA	27	131.9	11.2	3.3	125.0 - 139.0	-0.105	-0.581
69	PARIETAL ANG	PAA	27	133.0	16.5	4.1	126.0 - 142.0	0.689	-0.165
70	OCCIPITAL AN	OCA	27	119.4	30.2	5.5	109.0 - 128.0	0.004	-1.107

TABLE A-9. DESCRIPTIVE STATISTICS OF THE LARSON MALE CRANIOMETRICS (IN MM)

VARIABLE		CODE NAME	N	MEAN	VARIANCE	STD. DEV.	RANGE	SKEWNESS	KURTOSIS
1	GLAB-OCC L	GOL	56	181.8	34.5	5.9	169.0 - 195.0	0.044	-0.680
2	NASIO-OCC L	NOL	56	179.5	30.6	5.5	167.0 - 193.0	0.117	-0.235
3	BAS-NAS L	BNL	56	103.4	15.2	3.9	91.0 - 111.0	-0.640	0.758
4	BAS-BREG HT	BBH	56	134.6	17.3	4.2	125.0 - 143.0	-0.011	-0.820
5	MAX CRAN BR	XCB	56	140.4	12.9	3.6	133.0 - 151.0	0.498	-0.136
6	MAX FRON BR	XFB	56	116.3	12.9	3.6	109.0 - 124.0	0.020	-0.851
7	BISTEPH BR	STB	56	109.4	24.1	4.9	93.0 - 118.0	-0.837	1.389
8	BIZYGO BR	ZYB	56	140.3	19.6	4.4	129.0 - 148.0	-0.504	-0.122
9	BIAURIC BR	AUB	56	129.4	18.8	4.3	118.0 - 138.0	-0.166	-0.365
10	MIN CRAN BR	WCB	56	74.9	9.3	3.0	66.0 - 81.0	-0.456	0.378
11	BIASTER BR	ASB	56	106.4	13.1	3.6	99.0 - 113.0	-0.008	-0.775
12	BAS-PROSTH L	BPL	56	100.3	19.6	4.4	88.0 - 114.0	0.368	1.907
13	NAS-PROSTH H	NPH	56	73.2	14.4	3.8	66.0 - 82.0	0.388	-0.494
14	NASAL HT	NLH	56	54.8	6.3	2.5	50.0 - 61.0	-0.018	-0.370
15	ORBIT HT (L)	OBH	56	35.8	4.2	2.0	31.0 - 40.0	0.051	-0.286
16	ORB BR (L)	OBB	56	40.5	2.3	1.5	38.0 - 43.0	-0.069	-0.894
17	BIJUGAL BR	JUB	56	121.5	16.9	4.1	110.0 - 129.0	-0.817	0.871
18	NASAL BR	NLB	56	26.0	2.2	1.5	23.0 - 30.0	0.028	-0.146
19	PALATE BR	MAB	56	65.7	9.9	3.1	55.0 - 71.0	-0.866	0.905
20	MASTOID HT	MDH	56	29.2	8.7	3.0	20.0 - 35.0	-0.287	0.637
21	MASTOID WDTH	MDB	56	11.5	2.9	1.7	8.0 - 15.0	-0.173	-0.362
22	BIMAXILL BR	ZMB	56	103.1	22.9	4.8	94.0 - 117.0	0.366	-0.005
23	ZYGOMAX SUBT	SSS	56	25.8	4.7	2.2	21.0 - 31.0	0.014	-0.176
24	BIFRONT BR	FMB	56	100.1	10.7	3.3	92.0 - 106.0	-0.515	-0.297
25	NAS-FRON SUB	NAS	56	17.9	5.2	2.3	13.0 - 23.0	-0.193	0.027
26	BIORBITAL BR	EKB	56	99.7	9.2	3.0	92.0 - 106.0	-0.371	-0.386
27	DACRYON SUBT	DKS	56	11.8	3.9	2.0	8.0 - 16.0	0.118	-0.686
28	INTERORB BR	DKB	56	21.4	4.3	2.1	18.0 - 27.0	0.585	0.215
29	NAS-DAC SUBT	NDS	56	11.0	1.6	1.2	8.0 - 14.0	-0.158	-0.005
30	SIMOTIC CHRD	WNB	56	9.1	2.9	1.7	6.1 - 13.3	0.309	-0.681
31	SIMOTIC SUBT	SIS	56	4.2	1.0	1.0	1.9 - 6.2	-0.149	0.060
32	MALR L (INF)	IML	56	36.5	9.7	3.1	30.0 - 42.0	-0.356	-0.660
33	MALR L (MAX)	XML	56	54.2	10.1	3.2	47.0 - 60.0	-0.017	-0.777
34	MALAR SUBT	MLS	56	10.3	1.7	1.3	8.0 - 13.0	-0.083	-0.947
35	CHEEK HEIGHT	WMH	56	24.4	3.7	1.9	20.0 - 28.0	-0.222	-0.424

TABLE 4-9 CONTINUED

VARIABLE	CODE NAME	N	MEAN	VARIANCE	STD. DEV.	RANGE	SKEWNESS	KURTOSIS
36 SUPORB PROJ	SOS	56	6.7	1.2	1.1	4.0 - 9.0	0.288	0.243
37 GLABEL PROJ	GLS	56	3.3	1.4	1.2	1.0 - 7.0	0.619	0.618
38 FOR MAGNUM L	FOL	56	36.8	7.2	2.7	31.0 - 42.0	-0.413	-0.637
39 NAS-BREG CHO	FRC	56	112.1	13.0	3.6	104.0 - 119.0	-0.196	-0.605
40 NAS-BREG SUB	FRS	56	23.1	3.4	1.9	20.0 - 27.0	0.273	-0.515
41 NAS-SUB FRAC	FRF	56	50.8	16.0	4.0	41.0 - 59.0	-0.153	-0.254
42 BREG-LAM CHO	PAC	56	109.7	30.0	5.5	95.0 - 124.0	0.137	0.520
43 BREG-LAM SUB	PAS	56	23.8	8.0	2.8	15.0 - 32.0	0.045	2.210
44 BREG-SUB FRC	PAF	56	54.8	44.0	6.6	34.0 - 69.0	-0.496	0.537
45 LAM-OPIS CHO	OCC	56	94.8	21.3	4.6	85.0 - 105.0	-0.093	-0.362
46 LAM-OPIS SUB	OCS	56	28.5	11.4	3.4	21.0 - 39.0	0.548	0.594
47 LAM-SUB FRAC	OCF	56	46.4	39.8	6.3	35.0 - 68.0	0.840	1.247
48 VERTEX RAD	VRR	56	121.1	12.9	3.6	113.0 - 129.0	-0.013	-0.230
49 NASION RAD	NAR	56	96.1	19.9	4.5	80.0 - 105.0	-0.831	2.087
50 SUBSPINAL RD	SSR	56	98.2	11.8	3.4	91.0 - 108.0	0.456	0.292
51 PROSTHION RD	PRR	56	103.3	13.8	3.7	96.0 - 115.0	0.463	0.852
52 DACRYON RAD	DKR	56	84.5	13.4	3.7	77.0 - 96.0	0.249	0.761
53 ZYGORBIT RAD	ZOR	56	81.1	8.8	3.0	73.0 - 88.0	-0.003	0.213
54 FRONTOMAL RD	FMR	56	78.8	10.6	3.3	68.0 - 86.0	-0.508	1.161
55 ECTOCONCH RD	EKR	56	73.0	7.1	2.7	65.0 - 79.0	-0.367	0.414
56 ZYGOMAX RAD	ZMR	56	73.1	9.4	3.1	64.0 - 79.0	-0.399	0.273
57 MI ALVEOL RD	AVR	56	82.7	19.5	4.4	73.0 - 93.0	-0.174	-0.188
58 NASANG BA-PR	NAA	56	66.7	6.4	2.5	62.0 - 75.0	0.448	0.898
59 PROSAN NA-BA	PRA	56	71.3	7.8	2.8	66.0 - 77.0	0.112	-0.615
60 BASANG NA-PR	BAA	56	42.1	6.0	2.5	38.0 - 49.0	0.674	0.301
61 NASANG BA-BR	NBA	56	77.2	9.0	3.0	69.0 - 84.0	-0.081	0.058
62 BASANG NA-BR	BBA	56	54.3	5.6	2.4	50.0 - 62.0	0.585	0.531
63 ZYGOMAX ANG	SSA	56	126.7	16.7	4.1	118.0 - 136.0	0.180	-0.558
64 NAS-FRON ANG	NFA	56	140.7	16.0	4.0	132.0 - 151.0	0.434	-0.298
65 DACRYAL ANG	DKA	56	146.8	24.1	4.9	135.0 - 156.0	-0.205	-0.483
66 NAS-DACR ANG	NDA	56	88.7	56.6	7.5	74.0 - 108.0	0.234	0.009
67 SIMOTIC ANG	SIA	56	95.1	208.6	14.4	70.0 - 139.0	0.814	0.842
68 FRONTAL ANG	FRA	56	134.9	9.0	3.0	127.0 - 140.0	-0.222	-1.275
69 PARIETAL ANG	PAA	56	132.8	16.1	4.0	119.0 - 144.0	-0.092	2.113
70 OCCIPITAL AN	OCA	56	117.7	27.8	5.3	102.0 - 131.0	-0.302	0.622

TABLE A-10. DESCRIPTIVE STATISTICS OF THE LARSON FEMALE CRANIOMETRICS (IN MM)

VARIABLE		CODE NAME	N	MEAN	VARIANCE	STD. DEV.	RANGE	SKEWNESS	KURTOSIS
1	GLAB-OCC L	GOL	62	173.3	26.5	5.2	163.0 - 183.0	-0.116	-0.977
2	NASIO-OCC L	NOL	62	172.1	24.7	5.0	161.0 - 182.0	-0.127	-0.607
3	BAS-NAS L	BNL	62	98.5	15.7	4.0	90.0 - 107.0	0.001	-0.382
4	BAS-BREG HT	BBH	62	128.9	28.5	5.3	113.0 - 141.0	-0.499	0.389
5	MAX CRAN BR	XCB	62	135.7	17.8	4.2	127.0 - 146.0	-0.070	-0.740
6	MAX FRON BR	XFB	62	112.0	15.2	3.9	101.0 - 120.0	-0.431	0.237
7	BISTEPH BR	STB	62	107.7	30.1	5.5	94.0 - 117.0	-0.617	-0.059
8	BIZYGO BR	ZYB	62	129.8	22.9	4.8	115.0 - 143.0	-0.034	1.572
9	BIAURIC BR	AUB	62	122.8	22.8	4.8	111.0 - 133.0	-0.250	0.146
10	MIN CRAN BR	WCB	62	71.8	8.7	3.0	65.0 - 79.0	0.056	-0.103
11	BIASTER BR	ASB	62	102.1	11.4	3.4	92.0 - 108.0	-0.664	0.201
12	BAS-PROSTH L	BPL	62	97.4	13.1	3.6	89.0 - 108.0	0.205	0.062
13	NAS-PROSTH H	NPH	62	69.6	12.0	3.5	61.0 - 78.0	0.083	-0.329
14	NASAL HT	NLH	62	51.3	5.1	2.3	46.0 - 57.0	-0.094	-0.192
15	ORBIT HT (L)	OBH	62	35.1	3.1	1.8	31.0 - 39.0	0.085	-0.280
16	ORB BR (L)	OBB	62	39.5	2.5	1.6	36.0 - 43.0	0.072	-0.877
17	BIJUGAL BR	JUB	62	113.9	14.7	3.8	103.0 - 121.0	-0.618	0.394
18	NASAL BR	NLB	62	25.5	2.7	1.6	21.0 - 30.0	0.239	0.280
19	PALATE BR	MAB	62	63.0	9.4	3.1	56.0 - 69.0	-0.083	-0.453
20	MASTOID HT	MDH	62	26.2	6.6	2.6	20.0 - 33.0	0.028	0.060
21	MASTOID WDTH	MDB	62	9.1	2.6	1.6	5.0 - 13.0	-0.167	-0.118
22	BIMAXILL BR	ZMB	62	97.2	18.6	4.3	87.0 - 105.0	-0.220	-0.488
23	ZYGOMAX SUBT	SSS	62	24.7	5.3	2.3	20.0 - 31.0	0.339	0.111
24	BIFRONT BR	FMB	62	96.5	13.1	3.6	87.0 - 104.0	-0.482	0.290
25	NAS-FRON SUB	NAS	62	17.0	4.5	2.1	11.0 - 21.0	-0.124	0.078
26	BIORBITAL BR	EKB	62	96.5	10.1	3.2	88.0 - 103.0	-0.307	0.095
27	DACRYON SUBT	DKS	62	11.2	3.2	1.8	7.0 - 15.0	-0.321	-0.088
28	INTERORB BR	DKB	62	20.4	3.4	1.8	17.0 - 26.0	0.589	0.039
29	NAS-DAC SUBT	NDS	62	10.2	1.5	1.2	8.0 - 12.0	-0.071	-1.046
30	SIMOTIC CHRD	WNB	62	9.0	2.2	1.5	6.0 - 13.6	0.634	0.766
31	SIMOTIC SUBT	SIS	62	3.8	1.0	1.0	2.0 - 6.2	0.500	-0.158
32	MALR L (INF)	IML	62	34.1	10.1	3.2	27.0 - 43.0	0.067	0.224
33	MALR L (MAX)	XML	62	51.0	12.8	3.6	41.0 - 60.0	-0.226	0.786
34	MALAR SUBT	MLS	62	10.1	1.7	1.3	7.0 - 12.0	-0.151	-0.848
35	CHEEK HEIGHT	WMH	62	22.2	4.2	2.0	18.0 - 28.0	0.594	0.459

TABLE A-10 CONTINUED

VARIABLE	CODE NAME	N	MEAN	VARIANCE	STD. DEV.	RANGE	SKEWNESS	KURTOSIS
36 SUPORB PROJ	SOS	62	4.8	0.8	0.9	3.0 - 7.0	0.322	0.066
37 GLABEL PROJ	GLS	62	1.9	0.8	0.9	1.0 - 4.0	0.799	-0.301
38 FOR MAGNUM L	FOL	62	34.1	4.7	2.2	30.0 - 40.0	0.575	-0.121
39 NAS-BREG CHD	FRC	62	108.0	16.8	4.1	97.0 - 118.0	-0.532	0.255
40 NAS-BREG SUB	FRS	62	23.7	4.2	2.1	19.0 - 28.0	-0.347	0.285
41 NAS-SUB FRAC	FRF	62	47.5	9.5	3.1	40.0 - 55.0	-0.134	0.126
42 BREG-LAM CHD	PAC	62	105.5	21.6	4.6	94.0 - 122.0	0.361	1.220
43 BREG-LAM SUB	PAS	62	22.9	5.2	2.3	18.0 - 29.0	0.187	-0.322
44 BREG-SUB FRC	PAF	62	52.6	13.2	3.6	43.0 - 61.0	-0.129	0.070
45 LAM-OPIS CHD	OCC	62	92.5	20.4	4.5	84.0 - 105.0	0.871	0.883
46 LAM-OPIS SUB	OCS	62	27.1	7.2	2.7	21.0 - 34.0	0.166	-0.216
47 LAM-SUB FRAC	OCF	62	44.1	26.8	5.2	31.0 - 56.0	-0.068	-0.335
48 VERTEX RAD	VRR	62	116.7	13.7	3.7	110.0 - 126.0	0.363	-0.001
49 NASION RAD	NAR	62	92.2	14.8	3.8	82.0 - 101.0	-0.377	0.320
50 SUBSPINAL RD	SSR	62	94.1	10.9	3.3	84.0 - 106.0	0.291	2.921
51 PROSTHION RD	PRR	62	100.1	13.1	3.6	91.0 - 113.0	0.395	1.976
52 DACRYON RAD	DKR	62	81.3	15.2	3.9	73.0 - 96.0	0.755	2.310
53 ZYGORBIT RAD	ZOR	62	78.9	11.0	3.3	71.0 - 88.0	-0.019	0.322
54 FRONTOMAL RD	FMR	62	75.7	10.8	3.3	67.0 - 82.0	-0.392	-0.454
55 ECTOCONCH RD	EKR	62	70.2	8.6	2.9	63.0 - 76.0	-0.293	-0.236
56 ZYGOMAX RAD	ZMR	62	70.4	12.2	3.5	64.0 - 78.0	-0.062	-0.744
57 M1 ALVEOL RD	AVR	62	79.3	14.6	3.8	70.0 - 91.0	-0.081	0.791
58 NASANG BA-PR	NAA	62	68.3	6.9	2.6	63.0 - 76.0	0.645	0.652
59 PROSAN NA-BA	PRA	62	70.0	8.9	3.0	59.0 - 76.0	-0.702	1.610
60 BASANG NA-PR	BAA	62	41.6	4.8	2.2	35.0 - 46.0	-0.122	0.079
61 NASANG BA-BR	NBA	62	77.1	6.3	2.5	70.0 - 82.0	-0.512	0.727
62 BASANG NA-BR	BBA	62	54.8	5.1	2.3	51.0 - 61.0	0.456	-0.037
63 ZYGOMAX ANG	SSA	62	126.1	20.8	4.6	115.0 - 138.0	0.044	-0.122
64 NAS-FRON ANG	NFA	62	141.3	15.9	4.0	134.0 - 152.0	0.215	-0.201
65 DACRYAL ANG	DKA	62	147.7	21.9	4.7	138.0 - 159.0	0.392	-0.013
66 NAS-DACR ANG	NDA	62	90.3	65.3	8.1	77.0 - 108.0	0.339	-0.602
67 SIMOTIC ANG	SIA	62	100.1	157.3	12.5	77.0 - 124.0	0.176	-1.085
68 FRONTAL ANG	FRA	62	132.2	10.2	3.2	127.0 - 140.0	0.290	-0.847
69 PARIETAL ANG	PAA	62	132.9	12.5	3.5	122.0 - 140.0	-0.185	-0.146
70 OCCIPITAL AN	OCA	62	119.0	16.0	4.0	112.0 - 128.0	0.369	-0.455

TABLE A-11. SORTED WITHIN-GROUPS VARIMAX ROTATED FACTOR PATTERN

		FACTORS																
VARIABLE	CODE NAME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
55	EKR	.913																
53	ZOR	.893																
54	FMR	.855																
56	ZMR	.851													.268			
52	DKR	.812		.397														
50	SSR	.810											.366					
49	NAR	.793		.415														
51	PRR	.768								.407			.259					
57	AVR	.718	.264							.334								
3	BNL	.697	.274	.288														
12	BPL	.682								.515								
17	JUB	.271	.800															
8	ZYB	.259	.762						.269									
26	EKB	.288	.730															.258
24	FMB	.260	.690	.251														
22	ZMB		.678	.301														
9	AUB		.655						.462									
10	WCB		.624															
19	MAB		.563															
27	DKS			.884														
65	DKA			-.875														
25	NAS			.871														
64	NFA			-.868			-.259											
45	OCC				.948													
70	OCA				-.858							.258						
1	GOL	.476			.601												.383	
2	NOL	.462		.267	.593												.377	
60	BAA					.915												
13	NPH	.280				.847												
14	NLH					.773												
66	NDA						-.853											
29	NDS						.831											
31	SIS						.759											
67	SIA						-.684									.476		

TABLE A-11 CONTINUED

VARIABLE	CODE NAME	FACTORS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
43	PAS				-.287			.879										
42	PAC							.838										
44	PAF							.664										
69	PAA				.422			-.658									.301	
5	XCB		.326						.779									
6	XFB		.283						.714		.346							
7	STB								.699		.387							
59	PRA									-.850								
58	NAA					-.450				.774								
40	FRS										.907							
68	FRA										-.883							
4	BBH											.789						
61	NBA	-.295		-.277								.627		-.388				
45	OCC				-.530							.621						
48	VRR							.384	.430			.584						
23	SSS												.865					
63	SSA			-.257									-.864					
41	FRF													.743				
39	FRC										.440			.642				
62	BBA									.271	.382	-.431		.585				
32	IML	.304													.830			
33	XML	.298	.261												.775			
34	MLS														.630			
30	WNB															.821		
28	DKB		.406	.320												.540		
38	FOL																.777	
15	OBH					.420												.620
16	OBB		.486	.351			-.257											.523
35	WMH		.263			.482												-.453
37	GLS										-.285			.467				
47	OCF				.397			-.304	.345			.335					-.329	
11	ASB		.261		.316				.494								.317	
18	NLB	.341														.379		

VITA

Mark Frances Guagliardo was born on October 21, 1956, in Hammond, Louisiana. He graduated with High Honors from Southeastern Louisiana University in 1977 with a major in Zoology, with Highest Honors from The University of Tennessee, Knoxville the same year with a major in Anthropology, and received a Master of Arts in Anthropology from The University of Tennessee in 1980.

He has participated in archeological field work in Louisiana, Texas, Illinois and Tennessee. As a dermatoglyphics research assistant for Tennessee's Department of Anthropology, he collected finger and palm prints in Knoxville and the mountains of Oaxaca, Mexico. His research and publications have been in the areas of dental anthropology and skeletal biology.

At various times between 1973 and 1980 Mark served as a teaching assistant for introductory botany and anthropology classes. He held a Hilton A. Smith Graduate Fellowship from 1980-82. He was a visiting instructor in the Department of Sociology and Anthropology in the spring of 1979, and in the Department of Sociology, Virginia Polytechnic Institute and State University in the summer of 1981. He has accepted a Smithsonian Institution Postdoctoral Fellowship in anthropology for 1982-83 in order to expand the research of this dissertation.

Mark is a member of the American Association of Physical Anthropologists, Sigma Xi Scientific Research Society, Phi Kappa Phi, and Southeastern Louisiana University's "13" Club Honor Society. He is married to Kathleen Ann Jablonski, who is also a doctoral candidate in Tennessee's Department of Anthropology. They are expecting their first child in September of 1982.