To the Graduate Council:

I am submitting herewith a dissertation written by Terry Stewert Zobeck entitled "Postcraniometric Variation Among the Arikara." 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 Philosophy, with a major in Anthropology.

Richard L. Jantz
Major Professor

We have read this dissertation
and recommend its acceptance:

Accepted for the Council:

Vice Chancellor
Graduate Studies and Research

POSTCRANIOMETRIC VARIATION AMONG THE ARIKARA

A Dissertation

Presented for the

Doctor of Philosophy

Degree

The University of Tennessee, Knoxville

Terry Stewert Zobeck

June 1983

For Grandma

and John

ACKNOWLEDGMENTS

Though my name appears on the cover of this dissertation I do not deserve sole credit for the accomplishment it represents. Several people deserve to share this credit, they have my everlasting gratitude.

First, are the members of my doctoral committee. Dr. Richard L. Jantz, my major professor, provided first-rate guidance throughout, never once losing patience with my sometimes frantic questions. Throughout my graduate career he has done more than just dispense information and facts, he has motivated me beyond my preconceived limitations. Dr. Fred H. Smith, in addition to being a special friend, has taught me the meaning of the word "teacher"; he has always been an exemplary one. A special thanks goes to Dr. William M. Bass, without whose pioneering work in Plains anthropology and strong support of my career this dissertation would not have been written. Dr. Richard J. Jendrucko was of great assistance in the editing stage of this work, his comments were always lucid and helpful.

I would especially like to thank Dr. Douglas Owsley for showing such faith in a neophyte osteologist. His support and friendship helped to pull me through some of the rough spots, not to mention two wonderful trips to Washington, D.C., and an introduction to the joys of fresh seafood.

A warm thanks is extended to Dr. Walter Klippel for hiring me onto various archaeological projects under his administration. These jobs provided financial support when it was desperately needed, thereby enabling me to continue work on this dissertation.

Thanks are extended to Dr. Douglas Ubelaker, of the Smithsonian Institution, for making the museum's collections available to me for study.

Among my close friends none deserves thanks more than William Baden. Bill's assistance on statistical matters was invaluable throughout my career at Tennessee. Even more important to me however, was his friendship.

I also owe a great debt of thanks to another close friend, Dr. Pat Key. Not only did Pat's work set an example for me to follow but, his companionship over a beer, a backgammon board, and a good record was much appreciated.

Two colleagues and friends at The University of Tennessee, Drs. P. Willey and Bruce Bradtmiller, provided substantial assistance. P., as curator of the anthropology department's skeletal collection, made working with the Arikara material much easier than it might have been. He also steered me towards several valuable references. Bruce, on several occasions, acted as a sounding board for developing ideas and made several useful suggestions.

A special heartfelt thanks go to my co-workers on the Arikara skeletal biology project, Cheryl Puskarich, Steve

Symes, and Henry Case. Cheryl and I served as recorders for one another during our respective data collection stages. Steve and I spent two summers together collecting data for the project and becoming good friends in the process. Henry, in addition to being a tireless collector of dental anthropometrics, showed all of us how to have a good time in Washington, D.C.

Special thanks go to several friends in Tennessee who through their friendship made the rigors of graduate life more endurable: Cliff and Donna Boyd, Marla Baden, Dr. Mark Guagliardo, Dr. Kathleen Jablonski, Ken Parham, Dr. Tony Cavender, Dr. Dave Glassman, Bonnie and John Joersche, Bill Rodriquez and Dr. Gerald Schroedl.

No amount of words can express the gratitude I feel towards a truly special lady, my mother-in-law, Elizabeth Houghton. She has always showed tremendous faith and support from the beginning.

This work could not have been undertaken, much less completed, without the unswerving support of my family, especially my mother, Alice Zobeck.

Most of all, I am indebted to my wife, Sandy, who deserves so much more than these words can express. Her support, faith, and love provided me with the motivation needed to keep me going through each step of my undergraduate and graduate careers.

Lastly, I would like to thank all of the practitioners of Rock and Roll, but especially the Beatles, John, Paul, George, and Ringo, for helping to keep me sane through it all.

Many of the specimens utilized here were originally excavated by Dr. William M. Bass under NSF grants GS-837, GS-2717 and GS-1635, and National Geographic Society Grant 699,912. I thank Dr. Bass for access to these materials. Data collection for this work was supported by NSF Grant BNS 8102650.

ABSTRACT

The postcraniometrics of the Arikara, a Plains Indian group, are analyzed to determine biological relationships. The sample studied is composed of 634 individuals from 10 archaeological sites, all from the state of South Dakota, and ranging in date from A.D. 1600 to 1832.

The data are analyzed with a variety of statistical methodologies; univariate as well as multivariate.

The results show a consistent patterning to the within-group variation, identifying common elements of postcranial structure. The groups analyzed however, show very little group heterogeneity along the lines of the intrapopulation variation. This is contrary to results obtained by several craniometric studies conducted on the Arikara. The results of the present analysis, in conjunction with those of others, tend to indicate that the postcranial skeleton is unusually homogeneous over broad ethnic categories.

An analysis of the patterns of Arikara sexual dimorphism indicate that despite a well documented increase in environmental stress over time, there is no change in the level of sexual dimorphism. These results tend to support the hypothesis of a strong genetic component to changing patterns of sexual dimorphism.

Future studies need to incorporate analyses of other Plains Indian groups in order to substantiate or disprove the results presented here.

Data collection for the work was supported by NSF Grant BNS 8102650.

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I. INTRODUCTION

Statement of Purpose

Howells has observed that ". . . population differences in cranial shape are based upon traits which have a common ground of individual genetic variation within all populations" (1973:146). Other research has supported this "universality" of cranial structure (e.g., Brown 1967; Key 1979). It is the general goal of the present study to determine whether Howells' statement can be modified to include the postcranial skeleton (for the present research the postcrania are limited to the long bones, scapula, and clavicle). The specific purpose is twofold: (1) to identify intrapopulation (within group) patterns of postcranial variation and (2) to determine the relationship of this variation to postcranial interpopulation (among group) variation. These goals will be accomplished by analyzing the data by means of multivariate statistical procedures that are designed to identify the structural patterns and their relationship to interpopulation differences. Corruccini (1975, 1978), Zegura (1978a), and Andrews and Williams (1973) have discussed the advantages and disadvantages of multivariate procedures in assessing biological relationships. Corruccini (1975:140-141) has proposed some general guidelines for morphometric analyses. Briefly summarized

they are: (1) justification for a morphometric approach as opposed to some other approach, (2) accurate definition and justification of the measurement set, (3) analysis must be competently done (i.e., several options should be covered, consideration of the distinction between size and shape, etc.), and (4) relate the multivariate results back to the original anatomy (i.e., the functional meaning of the results, if any, must be made explicit). These recommendations have been followed here.

It is beyond the scope of the present study to test the above hypothesis of a "universal" postcranial structure on a worldwide basis, as Howells has done for the crania. However, it is within the scope of the present study to approach this problem on a small, regional scale within a microevolutionary and culture-historical framework with the methodology proposed by Howells (1973). Key (1982) has demonstrated with craniometric data the usefulness of this adaptation of Howells' methodology to regional scale problems. This approach can be undertaken by analyzing data collected on several closely related populations that are restricted in space and time.

Such a sample is exemplified by the skeletal remains recovered from several archaeological sites that are representative of the Arikara, an Amerindian tribe of the Great Plains region of North America. As Jantz (1972:20) has stated:

> This material is particularly amenable to micro-evolutionary analysis for several reasons. First, it is circumscribed in time and space, ranging from about A.D. 1600 to 1830, and from Pierre to Mobridge, South Dakota, respectively. Second, the material is either historically documented as Arikara, or belongs archaeologically to the Coalescent tradition, thought by many to be ancestral to the Arikara (Wedel 1961:190-200; Hoffman 1967:75; Hurt 1970:207-13). Finally, environmental changes occasioned by European contact presented a situation conducive to biological change.

In conjunction with accomplishing the stated purposes certain associated questions will be addressed, including:

1. Do the postcrania paint the same picture of culture-historical relationships as do the crania?

2. Given the known environmental changes effecting the Arikara through time what are the patterns of sexual dimorphism as seen in the postcrania?

3. What conclusions can be drawn concerning the functional morphology of the postcranial skeleton?

Statement of Problem

Traditionally, the cranium has been the preferred morphological unit of analysis of physical anthropologists, from Blumenbach to the present. The reasons for this state of affairs are complex and numerous and while interesting they do not need to be discussed here. What is important is the effect they have had on the research designs of problems in skeletal biology. This effect is illustrated by the topic of a recent paper by Falk and Corruccini (1982) in

which the relative merits of cranial and dental measurements are compared for their ability to separate human populations. Postcranial measurements are not even considered relevant to their discussion. The present research is offered as an attempt to partially rectify the situation. The methodologies and research designs of various craniometric studies are applied to postcranial data with, among others, the aim of "separating human populations."

Thus, of particular relevance to the present research are the recent craniometric studies designed to determine population relationships on either a worldwide (Howells 1973), regional (Rosing and Schwidetzky 1977; Schwidetzky 1972; Schwidetzky and Rosing 1976; Konduktorova 1974; Pietrusewsky 1977), culture area (Bass 1964; Key 1982; Zegura 1971, 1975, 1978b) or ethnic group basis (Hausman 1982; Jantz 1972, 1973, 1974, 1977; Jantz et al. 1978; Key and Jantz 1981; Owsley and Jantz 1978). These studies share the common purpose of identifying patterns of cranial variation and how these patterns are related to population differences. Also, these studies are couched within frameworks of taxonomy, microevolution, culture-history or a combination of all three. In each case the results were highly interpretable within the context of the chosen framework. By way of example, Jantz (1977) was able to show morphological simularity between Arikara crania from the

Northern Plains and earlier, more southerly St. Helena crania. These results support previous archaeological hypotheses regarding the origin of the Coalescent Tradition (Arikara) from the Central Plains Tradition (St. Helena). This example also illustrates an assumption, usually tacit, made by such studies: groups with similar cranial morphologies are more closely related than groups with dissimilar cranial morphologies. I would propose to extend this assumption to include postcranial morphology.

All this is not meant to imply that the postcranium has been completely overlooked in skeletal biology, it has not. The postcranium has been extensively utilized in problems of forensic medicine, such as stature estimation (Trotter and Gleser 1952, 1958; Dupertius and Hadden 1951; Pearson 1899; Hrdlička 1939; Keen 1953; Stewart 1968), sex estimation (Dwight 1904/1905; Hanihara 1958; Pons 1955; Thieme and Schull 1957), and age estimation (Greulich and Pyle 1959; McKern and Stewart 1957; McKern 1957; Pyle and Hoerr 1955). Paleontologists and anatomists, addressing questions of taxonomy, evolution, and function of fossil and extant primates have consistently examined the postcranial skeleton (Oxnard 1963, 1967, 1972, 1973, 1975, 1977; Lewis 1972; Broom and Robinson 1950; Lovejoy 1975; Lovejoy et al. 1973; Lovejoy and Trinkaus 1980; Trinkaus 1976a, 1976b, 1977; Ogden 1974; Ljunggren 1975, 1976, 1979, 1980).

The postcranial skeleton has also been analyzed with respect to population differences. Of particular interest to the present study are several analyses of the femur. Holtby (1918) compared femoral measurements from modern and Middle Ages samples and concluded that there was little or no change in the femoral dimensions through time. Pearson and Bell (1919) compared the modern English femur to several other ethnic groups and concluded that the ordering of the relationships depended upon which measurements were included in the analysis. There are also numerous studies exploring population differences in stature and the level of sexual dimorphism (Eveleth 1975; Eveleth and Tanner 1975; Frayer 1980; Hiernaux 1968; Greulich 1951, 1957; Tobias 1972, 1975; Gray and Wolfe 1980; Brace 1973; Trinkaus 1980; Birkbeck and Lee 1973; Key 1980; Willey 1982). Positive and negative results are usually explained in terms of genetic, cultural, geographic, or nutritional factors.

Perhaps most intersting of all are several studies that have applied multivariate methodologies to postcranial data (Hammond 1957; Howells 1951, 1952; Lorr and Fields 1954; Rees 1950; Schrieder 1963; Skibinska 1977; Tanner 1964; Thurston 1947; Vandenberg 1968). These studies are of interest because they used either factor analysis or principal component analysis to reduce a large battery of measurements to several interpretable factors or components

of body structure, an analytical approach applied in the present analysis. For the most part however, these studies have been limited to analyses of living persons with the purpose of classifying body types. Their results will be discussed in further detail in later sections.

A second category of multivariate analysis of post-craniometric data is represented by the work of Lavelle (1974) and Van Gerven (1971, 1972). Both of these researchers worked with femoral data collected from archaeological populations. Van Gerven examined the contribution of the size and shape of the femur to patterns of sexual dimorphism. Part of his analysis was a principal component analysis of 17 measurements, some of which are used in the present study. With appropriate caution Van Gerven's results are compared in a later section with the results obtained by the present study. Lavelle (1974) measured femora ranging in time from the Bronze Age to the present. No clear pattern emerged until he standardized all values by maximum femur length. This resulted in a steady, though slight, progression of increasing dimensions through time. Even then the groups did not discriminate very well. A possible problem with Lavelle's analysis is that all of the variables were never analyzed together. Instead, Lavelle attempted to partition size and shape variables into separate analyses (i.e., all the linear dimensions at once,

all the angular dimensions at once, all the length dimensions at once, etc.). This approach would seem to neglect the complex nature of femoral structure and function. For example, the size of any particular angle is correlated with certain diameters or lengths, therefore measures of all three should be included in a single analysis.

The approach adopted here should overcome Lavelle's problem. Principal component analysis should identify morphological components of any given bone. These components may be a combination of angles, diameters, lengths, etc., thus combining factors of size and shape, and more closely approximating the underlying morphological relationships.

II. ARIKARA ARCHAEOLOGICAL FRAMEWORK

The archaeology of the Arikara has been discussed at length elsewhere (see Lehmer 1971; Lehmer and Jones 1968, for a detailed discussion and Jantz 1972, 1973; Key 1982, for excellent summaries) therefore, it will only be briefly outlined here.

The Arikara were one of many Amerindian tribes that occupied lands of the Plains area. Specifically, they occupied the Middle Missouri subarea, an archaeological spatial division encompassing the land drained by the Missouri River in North and South Dakota (Willey 1966:312). Linguistically, the Arikara are affiliated with the Caddoan speaking peoples of the Southern Plains, thus suggesting an ancestral origin in this area. Culturally, they are part of the Plains Village Pattern which makes its first appearance around A.D. 1000 and marks the establishment of agriculture in the area (Lehmer 1971:27). The Plains Village Pattern is usually divided into three cultural traditions; Central Plains, Middle Missouri, and Coalescent (Lehmer 1971:27) with a fourth, the peripheral Oneota tradition, added by some (e.g., Harvey 1979; Key 1982). The Central Plains and Middle Missouri traditions are roughly contemporaneous. Aspects of each went into the formation of the later Coalescent (Lehmer 1971:27). The Arikara are representative of the Coalescent Tradition.

The Coalescent Tradition, in turn, is usually divided into four temporal variants: Initial Coalescent (A.D. 1400-1550), Extended Coalescent (A.D. 1550-1675), Post Contact Coalescent (A.D. 1675-1780) and Disorganized Coalescent (A.D. 1780-1862) (Lehmer 1971:33). Only skeletal material from the last three variants is included in the present analysis.

The Coalescent Tradition is characterized as a period of migration, from the Loup River in Nebraska northward to the regions of South Dakota drained by the Missouri River. The initial migrations were met with some resistance if the Initial Coalescent fortified villages are any indication. These large fortified villages are not in keeping with the typical Central Plains settlement pattern of small scattered villages from which the Coalescent developed. The resistance was offered by peoples that are probably ancestral to the historic Mandan, a people that are culturally and biologically distinct from the Arikara (Jantz 1973).

As a result of the successful encroachment, friction was reduced in the succeeding Extended Coalescent. This is evidenced by a return, in most areas, to the typical scattered village settlement pattern.

The Post Contact Coalescent represents the fluorescence of the Arikara. Two important cultural factors contributed to their success at this time: the introduction of the

horse and the Arikara's role as middlemen in the fur trade. The acquisition of the horse from Spanish settlements to the southwest, while enabling the Arikara to become more efficient hunters also led to the establishment of powerful equestrian tribes on the Plains. Thus, while the Arikara's lot may have improved they also became the frequent targets of raids by the nomadic equestrians. These raids resulted in a return to a fortified village in some areas. The fortifications were not always successful as is evidenced by the Larson site (39WW2) massacre (Owsley et al. 1977). Initially, the Arikara's role as middleman in the fur trade brought prosperity. However, with increasing European contact came European diseases that devastated the Arikara as well as other tribes. One smallpox epidemic in 1781-82 is estimated to have killed 75% of the Arikara population (Lehmer and Jones 1968:71).

By the time of the Disorganized Coalescent the majority of the remaining Arikara were reduced to living in three large villages (Bass et al. 1971; Lehmer 1971; Smith 1972), down from a maximum estimate of 32 villages (Nasitir 1952: 299) in less than a century. The advent of the reservation period in 1862 marks the end of the Coalescent Tradition as well as the Plains Village Pattern.

III. DATA BASE

Sample

Postcranial data were collected from 634 individuals from 10 archaeological sites located along the Missouri River in South Dakota (see Figure 1, modified from Key 1982). The majority of the sites were excavated as part of the Missouri River Basin Survey, a salvage archaeology project begun in the mid-1940's. A large amount of skeletal material was recovered, juvenile as well as adult, post-cranial as well as cranial, the majority of which was excavated by Dr. William M. Bass with field crews from the University of Kansas. It was this commitment to the recovery of all skeletal material that has made this study, as well as many others, possible.

All ten sites are associated with the Arikara or their direct ancestors (Bass 1964; Bass et al. 1971; Hurt 1957; Hurt et al. 1962; Jantz 1972; Lehmer and Jones 1968; Sigstad and Sigstad 1973). Two of the sites, Mobridge (39WW1) and Sully (39SL4), are thought to contain more than one occupational component. Postcranial skeletal material are available from two Mobridge components, Mobridge Features 1 and 2; and from three Sully components, Sully A, D, and E. For the present analysis each component is considered as a separate analytical unit along with the eight single

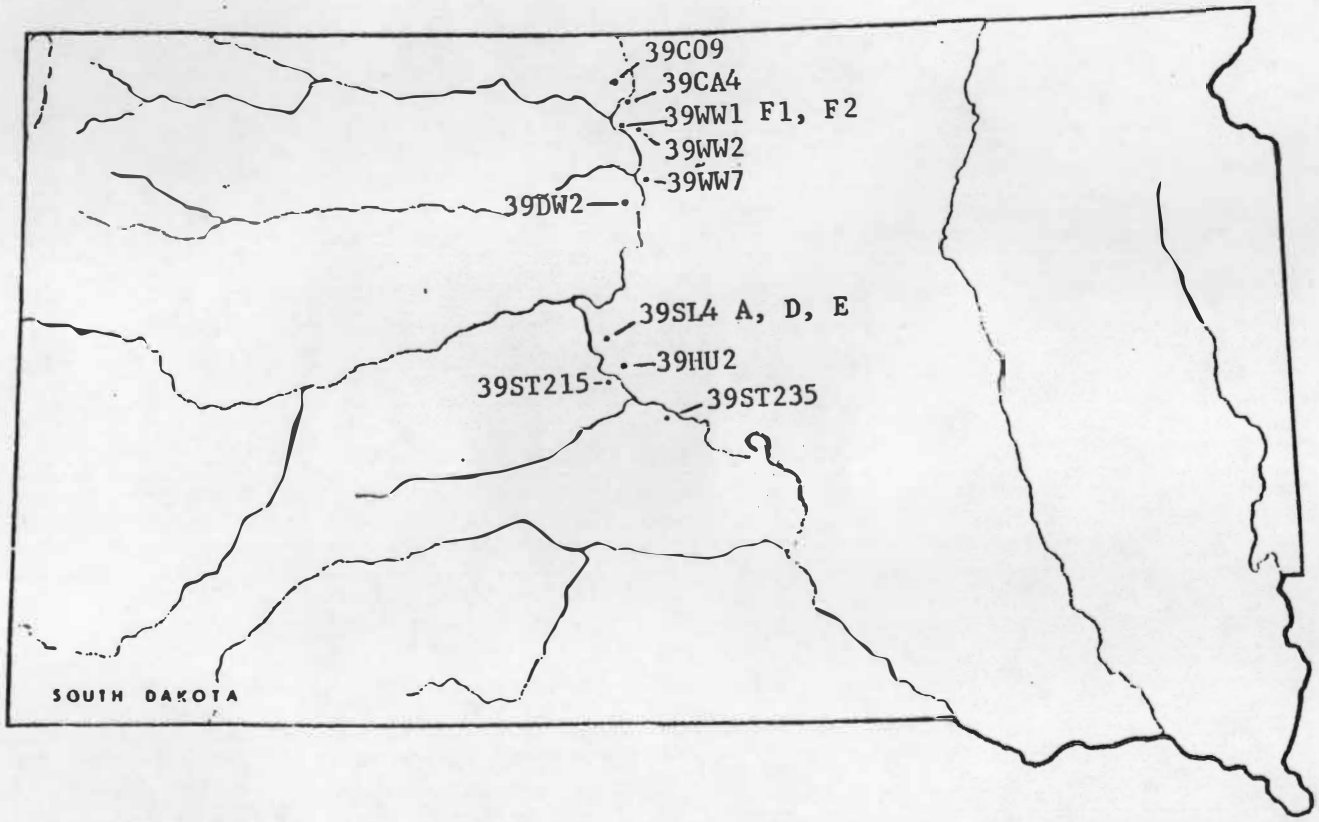


Figure 1. South Dakota Sites Yielding Skeletal Material.

component sites (some of the remaining eight sites are, in fact, multicomponent, however their sample sizes are so small that it would be fruitless to consider them as separate groups). This brings the number of groups available for analysis to thirteen. Table 1 (modified from Key 1982) presents the Smithsonian site code, name, date range, method of dating, median date, geographic coordinates, variant, and phase for each group.

All of the skeletal material is housed at either the Smithsonian Institution in Washington, D.C., or at The University of Tennessee, Knoxville.

Sex and Age Estimation

The present analysis is just one facet of a larger Arikara skeletal biology project currently underway (other facets include analyses of skeletal indicators of stress, paleopathology, growth, pelvic variation and dental variation). In order to facilitate the integration of the data and results of the various parts of the project, Dr. Douglas W. Owsley, principal investigator, made all of the sex and age determinations. While this process eliminates interobserver error the problem of intraobserver error remains. This source of error was reduced through reevaluation of any questionable specimen. Final judgment was made by Owsley in all cases.

Table 1. Site Data.

	Site	Name	Tribe	Date	Range	Method	Date	Geo	Coordin	Varnt	Phase
1	39ST235	Stony Point	Arikara	1740	1795	Arch	1767.5	44.31	100.09	PCC	Bad River 2
2	39WW1A	Mobridge F1	EC	1600	1650	Arch	1625.0	45.56	100.45	EC	La Roche
3	39WW1B	Mobridge F2	Arikara	1675	1700	Arch	1687.5	45.56	100.45	PCC	Le Beau 3
4	39WW2	Larson	Arikara	1679	1733	Arch	1706.0	45.52	100.41	PCC	Le Beau 3
5	39DW2	Four Bear	Arikara	1758	1774	Dend	±766.0	45.19	100.30	PCC	Le Beau 2
6	39SL4A	Sully A	EC	1663	1694	Dend	1678.5	44.59	100.58	EC	La Roche
7	39SL4D	Sully D	EC	1650	1675	Dend	1662.5	44.59	100.58	EC	La Roche
8	39SL4E	Sully E	Arikara	1675	1700	Dend	1687.5	44.59	100.58	PCC	Le Beau 1
9	39ST215	Leavitt	Arikara	1740	1792	Arch	1766.0	44.44	100.39	PCC	Bad River 2
10	39HU2	Oahe Village	Arikara	1675	1780	Arch	1627.5	44.47	100.56	PCC	Le Beau 1
11	39WW7	Swan Creek	Arikara	1675	1725	Arch	1700.0	45.31	100.29	PCC	Le Beau 2
12	39CA4	Rygh	EC	1600	1650	Arch	1625.0	45.64	100.38	EC	La Roche
13	39CO9	Leavenworth	Arikara	1802	1832	Hist	1817.0	45.67	100.36	DC	Hist. Arikara

Depending upon the applicability of the particular technique, adult age was estimated by: assessment of the morphological changes in the pubic symphysis (Gilbert and McKern 1973; McKern and Stewart 1957; Suchey et al. 1979), degree of epiphyseal closure (Krogman 1962; McKern and Stewart 1957), dental attrition (Miles 1963), and assessment of the morphological changes in the sacro-iliac articular surface (Lovejoy et al. n.d.). Only adults were included in the analysis; ages range from 15 to 60+ years of age.

Criteria selected for the estimation of sex include Phenice's (1969) pubic criteria and the standard morphological indicators (Bass 1971; Krogman 1962). Table 2 presents the number of males, females and totals for each group.

Table 2. Number of Males and Females for the Sample, by Group.

Group	Males	Females
Stony Point	3	6
Mobridge F1	27	29
Mobridge F2	66	47
Larson	104	94
Four Bear	3	8
Sully A	22	15
Sully D	23	21
Sully E	22	18
Leavitt	5	2
Oahe Village	6	1
Swan Creek	9	4
Rygh	16	13
Leavenworth	39	31
Totals	345	289

Variables

Complete definitions of all measurements, including the original source and required instrument are given in Appendix A. Measurements were collected to the nearest millimeter on the scapula, clavicle, humerus, radius, femur tibia and fibula of all adult specimens. Only complete bones were measured thus, eliminating missing data. A bone was judged complete if upon examination it was determined that all measurements could be collected. Quite often this was not possible without some estimation. Howells' (1973: 34) suggestion that a "guess" of the missing portion in the presence of the bone is probably the best form of estimate was followed here. For instance, if a small portion of a condyle was missing it was often possible to determine the extent of the missing portion by carefully studying the contours of the remaining portion. It was concluded that the advantages of estimating and including the bone in the analysis and thus, increasing sample size, outweighed the possible error introduced, especially in the case of groups with small sample sizes. In no case was a portion of the shaft estimated, rather only small missing portions of the proximal or distal ends of long bones or portions of the scapular body borders were estimated. Obvious pathological specimens were deleted from the analysis.

The present variable set was selected for its ability to reflect shape as well as size differences. Howells

(1973) has observed that many of the standard craniometric variables contribute significant information to the overall pattern of variation when subjected to multivariate analysis. The present analysis therefore includes many standard postcranial measurements. In addition, several measurements were designed specifically for the present analysis. The majority of the latter are angles designed to measure shape variation in the femur and scapula. Two angles (FNA, FCA) are measured directly from tracings of the femur with a protractor. Six scapular angles (VSA, LSA, ISA, SSA, CSA, MSA) are calculated from linear measurements with ANGLE, a fortran program written by Dr. Patrick Key. All angles are taken to the nearest degree. The number of measurements for each bone is: scapula 14; humerus 7; ulna 8; radius 3; femur 17; tibia 6; fibula 1; and clavicle 1. The total number of measurements is 57.

Each variable is assigned a three letter code. This shorthand method of naming variables was devised by Howells (1973) and is useful in several ways. It serves as the variable headings on coding forms and tables, and as the variable name in the input statements and variable lists of the various computer programs. Table 3 presents the variable name and code for each variable in the order in which they were taken.

Table 3. Code Names for Variables in Order of Use.

No.	Code Name	Variable Name	No.	Code Name	Variable Name
1	HML	Humerus-Maximum Length	30	APM	Femur-A-P Diameter Medial Condyle
2	BUE	Humerus-Breadth Upper Epiphysis	31	APN	Tibia-A-P Diameter Nutrient Foramen
3	RML	Radius-Maximum Length	32	MLM	Tibia-M-L Diameter Nutrient Foramen
4	UML	Ulna-Maximum Length	33	NFL	Tibia-Position Nutrient Foramen
5	FML	Femur-Maximum Length	34	SML	Scapula-Maximum Length
6	FOL	Femur-Oblique Length	35	SMB	Scapula-Maximum Breadth
7	FTL	Femur-Trochanteric Length	36	SLS	Scapula-Spine Length
8	TML	Tibia-Maximum Length	37	SSL	Scapula-Supraspinous Line Length
9	BPE	Tibia-Maximum Breadth Proximal Epiphysis	38	ISL	Scapula-Infraspinous Line Length
10	BDE	Tibia-Maximum Breadth Distal Epiphysis	39	GCB	Scapula-Glenoid Cavity Breadth
11	BML	Fibula-Maximum Length	40	GCH	Scapula-Glenoid Cavity Height
12	CML	Clavicle-Maximum Length	41	GIL	Scapula-Mid-Glenoid to Inferior Angle Length
13	MDS	Humerus-Midshaft Maximum Diameter	42	UPL	Ulna-Physiological Length
14	MDM	Humerus-Midshaft Minimum Diameter	43	FEB	Femur-Epicondylar Breadth
15	MDH	Humerus-Maximum Diameter Head	44	BCB	Femur-Bicondylar Breadth
16	EBR	Humerus-Epicondylar Breadth	45	LCS	Humerus-Shaft Least Circumference
17	RDH	Radius-Maximum Diameter Head	46	MCS	Radius-Shaft Maximum Circumference
18	BOP	Ulna-Maximum Breadth Olecranon Process	47	ULC	Ulna-Shaft Least Circumference
19	MBO	Ulna-Minimum Breadth Olecranon Process	48	VDN	Femur-Minimum Vertical Diameter Neck
20	WOP	Ulna-Maximum Width Olecranon Process	49	CCL	Femur-Capito-Collar Length
21	ORL	Ulna-Olecranon Process--Radial Notch Length	50	FNA	Femur-Neck Angle
22	OCL	Ulna-Olecranon Process--Coronoid Process Length	51	FCA	Femur-Condyle Angle
23	APD	Femur-Subtrochanteric A-P Diameter	52	VSA	Scapula-Vertebral Border Angle
24	MLD	Femur-Subtrochanteric M-L Diameter	53	LSA	Scapula-Lateral Border Angle
25	APS	Femur-Midshaft A-P Diameter	54	ISA	Scapula-Inferior Angle
26	MLS	Femur-Midshaft M-L Diameter	55	SSA	Scapula-Superior Angle
27	VHD	Femur-Vertical Head Diameter	56	CSA	Scapula-Caudal Angle
28	HHD	Femur-Horizontal Head Diameter	57	MSA	Scapula-Medial Angle
29	APL	Femur-A-P Diameter Lateral Condyle			

Measurement Error

Interobserver error was eliminated since the author measured all of the specimens. The following steps were taken to reduce interobserver error. Practice sessions with the variable set were held for one week prior to the actual beginning of the data collection. Approximately 60 individuals (10% of the total sample) were included in the practice data set. After the same 60 individuals were remeasured the two data sets were compared. Obvious discrepancies were noted and any refinement of the measurement technique made. The most troublesome measurements were the maximum and minimum breadth of the olecranon process (BOP and MBO, respectively). This is due to the indefinite nature of the landmarks defining the measurements. Great care was taken in ensuring the replicability of these measures but, I suspect that there may yet be some problem with them.

The data were entered into the DEC System 10 computer at The University of Tennessee, then checked for errors and any required corrections made.

Descriptive Statistics

Sample sizes, means and standard deviations for the entire sample, by group and sex are given in Tables B1, B-2 through B-4, and B-5 through B-7, Appendix B, respectively. All values were calculated by the MEANS procedure of SAS (SAS Institute, Inc. 1979).

IV. ANALYTICAL METHODS

Principal Component Analysis

One of the stated goals of the present analysis is to identify intragroup patterns of postcranial variation. Principal component analysis is ideally suited to this purpose (for detailed discussions of principal component analysis see Harman 1976; Morrison 1967). Briefly, principal component analysis is:

> primarily a data-transformation system through which the maximum variance in a measurement battery is sequentially extracted. In this manner the total variance of the original variables is orthogonally partitioned into successively smaller portions. In the process an observed set of correlated variables is transformed into an uncorrelated set; however, the explanation of variance is the focal point of the technique. (Zegura 1978a:152)

In general, the components identify independent structural dimensions along which populations vary. The populations can be drawn from many diverse fields including psychology (Spearman 1904), zoology (Jolicoeur and Mosimann 1960), anthropology (Andrews and Williams 1973; Jantz and Hawkinson 1980) and even literature (Blackith 1963). Whatever the data source, the components should always be interpreted and discussed in light of those data's "morphology" (Corruccini 1978). For osteological material this would include a discussion of the components in morphological and functional terms.

The interpretation of components is a somewhat subjective process that relies upon the interpretive skills of the researcher. However, if the component structure is straightforward and makes "morphological" sense then there should be no difficulty in interpretation. The actual process is accomplished by examination of the component "loadings" (the measure of the intensity and direction of the relationship between each variable and the given component; Van Gerven 1971:48). Any given component will have several significant variable loadings that define the nature of the component. There are several methods for determining the significance of variable loadings. The method adopted here is as follows: The component matrix is scanned across the columns for each variable. The highest loading for that variable on any component is noted. After all variables have been scanned the lowest loading for any variable on any component is identified; any loading greater than or equal to this value, on any component in the analysis, is also considered a significant loading (in the scapula, femur and all bones analyses some values that were slightly lower than the "lowest" value were included since they were much closer to the "lowest" value than they were to the remaining nonsignificant values, and in some instances they clarified the interpretation of the component). The significant loadings for each component are then

examined and through the interpretive skills of the researcher the interpretation of the component is achieved.

An excellent example of the interpretative process is provided by Key's (1982:81) interpretation of his prognathism component. Those variables that measure prognathism have the highest loadings, regardless of sign, on the component (for precise definitions of the variables see Howells 1973; Key 1982). The sign indicates the direction of the relationship:

Basion-Prosthion Length	.76	Prosthion Radius	.65
External Alveolar Breadth	.32	Nasion Angle	.83
External Alveolar Length	.72	Prosthion Angle	-.78
Subspinale Radius	.65		

This example shows that for the crania, principal components identifies a structural dimension of prognathism. It also indicates the relationship of the variables to the component; as prognathism increases the nasion angle grows more obtuse and the prosthion angle more acute.

The present analysis differs somewhat from traditional uses of principal component analysis in that the components are extracted from the pooled within-groups correlation matrix rather than the usual total correlation matrix. While correlation values may differ between males and females separate principal components analyses failed to show any difference in component structure. Each analysis produced four components after rotation. Correlations between individual male and female components were

calculated with RELATE, a fortran program from Veldman (1967). Results reveal that correlation values are quite high for all four comparisons (over .90 in each case). Thus, pooling of the sexes is probably justified.

The extraction of principal components from the pooled within-groups correlation matrix requires several computational steps that can easily be carried out with various procedures of SAS (SAS Institute, Inc. 1979). In all, six complete analyses were carried out; one each for bones with a sufficient number of variables (scapula, humerus, ulna, femur, and tibia) and one for all bones combined. The steps are:

1. For each group (with n > 5), by sex, a covariance matrix is calculated with the CORR procedure of SAS (SAS Institute, Inc. 1979). Sexes were calculated separately to reduce the effects of size.

2. The individual group covariance matrices are converted into Sums of Squares and Cross Product (SSCP) matrices and then summed to produce the pooled SSCP matrix with the MATRIX procedure of SAS (SAS Institute, Inc. 1979). Key (1982:67) has observed that "Pooling SSCP matrices rather than individual group variance-covariance matrices weighs the contribution of each group according to sample size . . ."; a desirable effect when working with samples of unequal sizes as is the case here.

3. The within-groups standard deviations are extracted from the pooled SSCP matrix. The standard deviations are used in the calculation of individual component scores (see below).

4. The pooled within-groups SSCP matrix is converted into a pooled within-groups correlation matrix with the MATRIX procedure of SAS (SAS Institute, Inc. 1979). The degrees of freedom for each matrix are:

Scapula	244	Femur	350
Humerus	399	Tibia	385
Ulna	350	All Bones	123

5. The principal components are extracted from the pooled within-groups correlation matrix with the FACTOR procedure (method = PRIN) of SAS (SAS Institute, Inc. 1979). Those components with eigenvalues greater than or equal to 1.0 were retained and rotated with the VARIMAX option of SAS (SAS Institute, Inc. 1979), all others were discarded. The analysis also produces a component score coefficient matrix for the calculation of individual component scores (see below).

6. Principal component scores for each individual are calculated with the SCORE procedure of SAS (SAS Institute, Inc. 1979). Each individual's raw data vector is converted into z-scores (with means of 0 and the within-groups standard deviations from step 3). The z-scores are multiplied by the component score coefficient matrix

produced in step 5. The resulting principal component scores have a mean of 0 and a standard deviation of 1. The component scores can then serve as the input data for any subsequent analysis.

Multiple Analysis of Variance

A second goal of the present research is to determine the relationship of the intragroup patterns of variation to the intergroup variation. In other words, the goal is to identify along which components the intergroup variation occurs. Multivariate analysis of variance (MANOVA) is the analytical method chosen to achieve this goal.

MANOVA tests first, for overall group heterogeneity for each treatment and second, indicates, by way of analysis of variance (ANOVA), along which components the heterogeneity (if any) occurs.

Six two-way MANOVAs were calculated, one for each individual bone and one for all bones combined, with the GLM procedure of SAS (SAS Institute, Inc. 1979). The treatments analyzed are Group, Sex and their Interaction. The principal component scores are the dependent variables. The general model for all of the analyses is:

$$\text{Component Scores} = \text{Group} + \text{Sex} + \text{Interaction} \qquad (4\text{-}1)$$

The analysis calculates two sets of Sums of Squares (SS): Type I and Type IV. Type I SS represent the

sequential breakdown of the model SS. Type IV SS are more conservative in that they represent the model SS for each effect conditioned on the others. In all of the present analyses the design is unbalanced. To offset the unbalanced designs all of the ANOVAs' tests of significance are calculated with the Type IV SS. These are the preferred tests of significance with unbalanced designs because of their conservative nature.

For detailed, mathematical discussions of Multiple analysis of variance see Morrison (1967) and Tatsuoka (1971).

V. RESULTS

Principal Component Analysis

Scapula

Four principal components with eigenvalues greater than 1.0 were extracted from the pooled within-groups correlation matrix. They account for 83% of the total variation. Appendix Tables C-1 and D-1 are the correlation and rotated principle component matrices, respectively.

The lowest final communality estimates are 0.43 and 0.41 for glenoid cavity breadth and height, respectively. The low values indicate that these variables have low correlations with each other and with the remaining variables which in turn suggests that these variables possess information extraneous to the common structure of the variable set. This is not surprising since the majority of the remaining variables measure aspects of the scapular body rather than the glenoid cavity.

The lowest salient loading for any single component, regardless of sign, is 0.39 for LSA on component 3. All loadings greater than or equal to 0.39 are considered in the interpretation of the components.

1. General Scapular Size. This is an important component accounting for 27% of the total variation. Highest loadings are on measures of scapular body length

(SML, GIL, ISL). More moderate loadings are on measures of glenoid cavity size (GCB, GCH). Their moderate loadings on this component indicate the contribution glenoid cavity size makes to overall scapular size. Slightly lower loadings are found for measures reflecting scapular body breadth (SLS, SMB). The signs of the correlations are all positive. Salient loadings are:

SML	0.88	GCB	0.63
SMB	0.54	GCH	0.63
SLS	0.60	GIL	0.84
ISL	0.76		

2. Vertebral Border Angles. This component accounts for 21% of the total variation. It defines the shape of the vertebral border. All three angles from this area have high loadings (CSA, MSA, SSA). The relationship of the angles to the component can be seen in Figure 2. The fourth significant loading is for the measure of the distance of the superior border (defined by the superior most point of the border) from the point of intersection of the scapular spine and the vertebral border (SSL). The direction of the signs indicate that as the distance of the superior border from the vertebral border increases the superior and inferior angles (SSA, CSA) grow more obtuse and the medial angle (MSA) grows more acute. This pattern would produce an

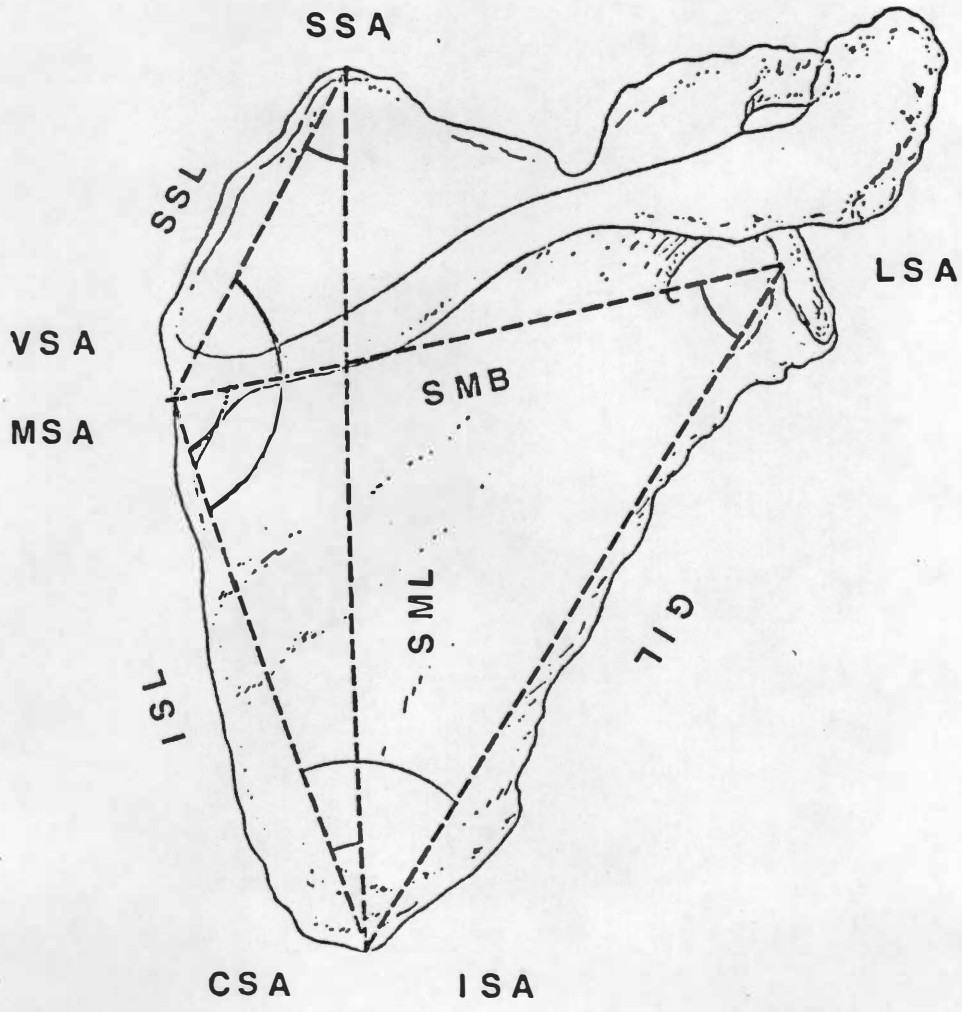


Figure 2. Angles of the Scapula.

overall shortening of scapular length. Salient loadings are:

SSL	0.69	CSA	0.97
SSA	0.76	MSA	-0.90

3. Breadth and Shape of the Scapular Body. This component accounts for 16% of the total variation. It clearly measures breadth and its relationship to body shape. The highest loading is on the inferior angle (ISA). Loadings are somewhat lower for the linear measurements of breadth (SMB, SLS). Both of these measures loaded significantly on component 1. This is not surprising since component 1 measures general size and breadth is a significant factor of size. Secondary to the higher loadings on the component is the lower loading on the lateral border angle (LSA). The relationship of the angles to the component can be seen in Figure 2. As the breadth of the scapula increases the inferior angle grows more obtuse. As a natural result the lateral border angle grows more acute. In light of this relationship between the angles it is somewhat surprising that the complementary vertebral border angle (VSA) does not load significantly on this component. Significant loadings are:

SMB	0.77	LSA	-0.39
SLS	0.61	ISA	0.94

4. Length and Shape of the Scapular Body. This component accounts for 19% of the total variation. It measures the length of the scapular body and its relationship to the shape of the body. The highest loadings are on the vertebral and lateral border angles (VSA, LSA). Moderate loadings are on the measures of body length (ISL, GIL) and the superior border angle (SSA). The relationship of the angles to the component can be seen in Figure 2. As the vertebral border (ISL) decreases the lateral border (GIL) increases in length. This relationship has the effect of medially displacing the apex of the inferior border. The effect upon the angles is that the lateral and superior angles (LSA and SSA, respectively) grow more acute as the medial border angle (MSA) grows more obtuse. The net effect of this pattern is a shortening of the length of the scapula. Since the components represent independent structural features, the length related changes in shape are independent of the breadth related changes in shape (component 3). It is a small point of interest that the inferior angle (ISA) does not load significantly on this component since the inferior border is so involved in the component. Salient loadings are:

ISL	-0.51	VSA	0.95
GIL	0.41	SSA	-0.46
LSA	-0.88		

Humerus

Two principal components with eigenvalues greater than 1.0 were extracted from the pooled within-groups correlation matrix. They account for 70% of the total variance. Appendix Tables C-2 and D-2 are the correlation and rotated principal component matrices, respectively.

Final communality estimates for four of the seven variables, HML, MDS, MDM, and EBR, are unfortunately, low (0.51, 0.66, 0.66 and 0.53, respectively) thus, indicating that these variables are not highly correlated with each other or with the remaining variables. While low correlation values between maximum humeral length (HML) and shaft diameters (MDS, MDM) are not surprising, a low value between the diameters is. It is possible that measurement error is contributing to the low values. However, all four measurements are standard postcraniometric variables; the points that define them are easily determined and the measurements are highly replicable.

The lowest salient loading for any single component, regardless of sign, is 0.41 for EBR on component 2. All loadings greater than or equal to 0.41 are included in the interpretation of the components.

1. Epiphyseal Size. This is an important component accounting for 37% of the total variation. The component measures the general size of the epiphyses. Highest

loadings are on the measures of the size of the proximal end (BUE, MDH). The magnitude of the loadings diminishes with maximum length (HML) and epicondylar breadth (EBR). The significant loading for HML suggests the significance of shaft length to epiphyseal size. All loadings are positive. In general, individuals with long shafts also have robust proximal and distal ends. Salient loadings are:

HML	0.68	MDH	0.90
BUE	0.88	EBR	0.60

2. Shaft Robusticity. This component is slightly less important than component 1. It accounts for 33% of the total variance. The component measures the robustness of the shaft. All of the significant loadings are on dimensions of the shaft, with the highest being on the least circumference of the shaft (LCS) and lower loadings on the midshaft diameters (MDH, MDS). All loadings are positive. Salient loadings are:

MDS	0.78	LCS	0.91	MDM	0.79

Ulna

Three principal components with eigenvalues greater than 1.0 were extracted from the pooled within-groups correlation matrix. They account for 67% of the total variance. Appendix Tables C-3 and D-3 are the correlation and rotated principal component matrices, respectively.

The lowest final communality estimates are 0.49 and 0.17 for maximum and minimum breadth of the olecranon process (BOP and MBO, respectively). In this case measurement error is probably the cause of the low correlations between these variables and the other ulnar variables. The breadth of the olecranon process is an important dimension to measure; however, these two variables are not the means with which to measure it. The points defining them, especially MBO, are very indefinite, due mainly to the great variability in the shape of the process' articular surface. Measures independent of the articular surface need to be designed. Any future analyses will drop BOP and MBO, as defined here, and replace them with more precisely defined measurements.

The lowest salient loading for any single component, regardless of sign, is 0.37 for MBO on component 3. All loadings greater than or equal to 0.37 are included in the interpretation of the components.

1. General Robusticity. This component accounts for 21% of the total variation. It measures overall robustness of the ulna. The highest loading is on the least circumference of the shaft (ULC). Slightly lower loadings are on width and breadth dimensions of the olecranon process (WOP and BOP, respectively). All loadings are positive. Individuals with robust shafts, in general, have robust olecranon processes. Significant loadings are:

BOP	0.61	ULC	0.80	WOP	0.74

2. Ulnar Length. This component accounts for 25% of the total variation. Its interpretation is straightforward. Only two variables load significantly on this component, maximum length (UML) and physiological length (UPL). The relationship between them is obvious. Salient loadings are:

UML	0.94	UPL	0.96

3. Articular Surface Size. Twenty-one percent of the total variation is accounted for by this component. It measures the length and breadth of the olecranon process' articular surface. The highest loading is on the measure of the length of the surface that articulates with the trochlea of the humerus (OCL). The length of the surface that articulates with the head of the radius (ORL) has a slightly lower loading. The lowest loading is on the minimum breadth of the articular surface (MBO). All signs are positive. This relationship can be broadly interpreted as indicating a positive correlation between the three elements of the elbow joint (ulna, radius, and humerus) since large trochlear and radial articular surfaces indicate large trochleae and radial heads. This suggestion is supported by the results of the All Bones Combined principal component analysis (see component 8 of that analysis). Salient loadings are:

MBO	0.37	OCL	0.86	ORL	0.79

Femur

Four principal components with eigenvalues greater than 1.0 were extracted from the pooled within-groups correlation matrix. They account for 72% of the total variation. Appendix Tables C-4 and D-4 are the correlation and rotated principal component matrices, respectively.

Six variables, MLD, BCB, VDN, CCL, FNA, and FCA have slightly low final communality estimates (0.58, 0.57, 0.55, 0.50, 0.53, and 0.48, respectively). Despite the low values, the majority of these variables figure prominently in the interpretation of the components.

Several of the measurements collected on the femur here are similar or identical to measurements used by Van Gerven (1971) in his principal component analysis of the femur. Any comparison between the present results and Van Gerven's should be viewed with caution since the variable sets and methodologies (his component structure is unrotated as is evidenced by the greater dispersion of the cumulative portions of the total variance; rotation tends to assign the variance more evenly) are not identical. However, some comparisons can still be made. Even though the measurement sets may not be the same they are measuring many of the same functional components of the femur. This seems to be supported by a comparison of results. Like the present results, Van Gerven's analysis produced four principal

components. They account for 75% of the total variation, approximately the same amount as the present analysis. The morphological interpretations of Van Gerven's components 1, 2, and 4 roughly correspond to the present analysis' components 1, 2, and 4. There is no analogue in the present analysis to Van Gerven's component 3, which measures femoral shape and torsion, since the present analysis does not include a measure of torsion.

The lowest salient loading for any single component, regardless of sign, is 0.32 for MLS on component 1. All loadings greater than or equal to 0.32 are considered in the interpretation of the components.

1. General Femoral Size. This is an important component accounting for 29% of the total variation. It defines general size, especially robusticity of the shaft and epiphyses. High loadings are on measures of the proximal (VHD, HHD) and distal (APL, APM, FEB, BCB) epiphyses. The vertical diameter of the neck (VDN) has an intermediate loading. Lower loadings are on the medio-lateral diameters of the shaft (MLD, MLS) and the three measures of femur length (FML, FOL, FTL). All signs are positive. Salient loadings are:

FML	0.34	HHD	0.85
FOL	0.34	APL	0.79
FTL	0.33	APM	0.76

MLD	0.39	FEB	0.86
MLS	0.32	BCB	0.72
VHD	0.85	VDN	0.58

This component corresponds to Van Gerven's component 1 (1971:48-49). Similar variables have similarly high loadings: bicondylar length (femur length), medio-lateral neck diameter, medio-lateral head diameter, epicondylar breadth, medio-lateral subtrochanteric diameter and medio-lateral mid-shaft diameter. While the two components each have unique variable loadings, there are still enough similarities to conclude that both components are measuring general size.

2. Shape of the Proximal Femur. This component accounts for 14% of the total variation. Most of the significant loadings are on measures of the proximal femur. The highest loadings are on the femur neck angle (FNA) and the medio-lateral diameters of the shaft (MLD and MLS). Lower loadings are on the anterio-posterior subtrochanteric diameter (APD) and the capito-collar length (CCL). This component is approximately analogous to Van Gerven's component 2. He obtains high loadings for femur neck angle, neck length, and medio-lateral midshaft diameter (1971:53). The signs on Van Gerven's component are reversed from the present analysis' but, the interpretation of the relationship is unchanged. The relationship of the angle to the

component can be seen in Figure 3. As the femur neck angle grows more obtuse the shaft dimensions and neck length decreases. Unique to the present analysis is the complementary relationship between FNA and FCA (bicondylar angle). Salient loadings are:

APD	0.36	CCL	0.57
MLD	0.64	FNA	-0.72
MLS	0.73	FCA	0.43

3. Femur Length. This component accounts for 19% of the total variance. It appears to be measuring femur length, yet emphasizing the contribution of the proximal end to overall length. All three femoral length measures (FML, FOL, FTL) have high loadings. However, the two that incorporate the most proximal end (FML and FOL) have identical high loadings. The third, which measures trochanteric length (FTL) and thus does not include the most proximal end, has a somewhat lower loading. The only other variable with a significant loading on the component is capito-collar length (CCL) which, to some extent, is the measure of that portion of the femur not included in trochanteric length. All signs are positive. There is no analogue in Van Gerven's analysis. Salient loadings are:

FML	0.92	FTL	0.86
FOL	0.92	CCL	0.35

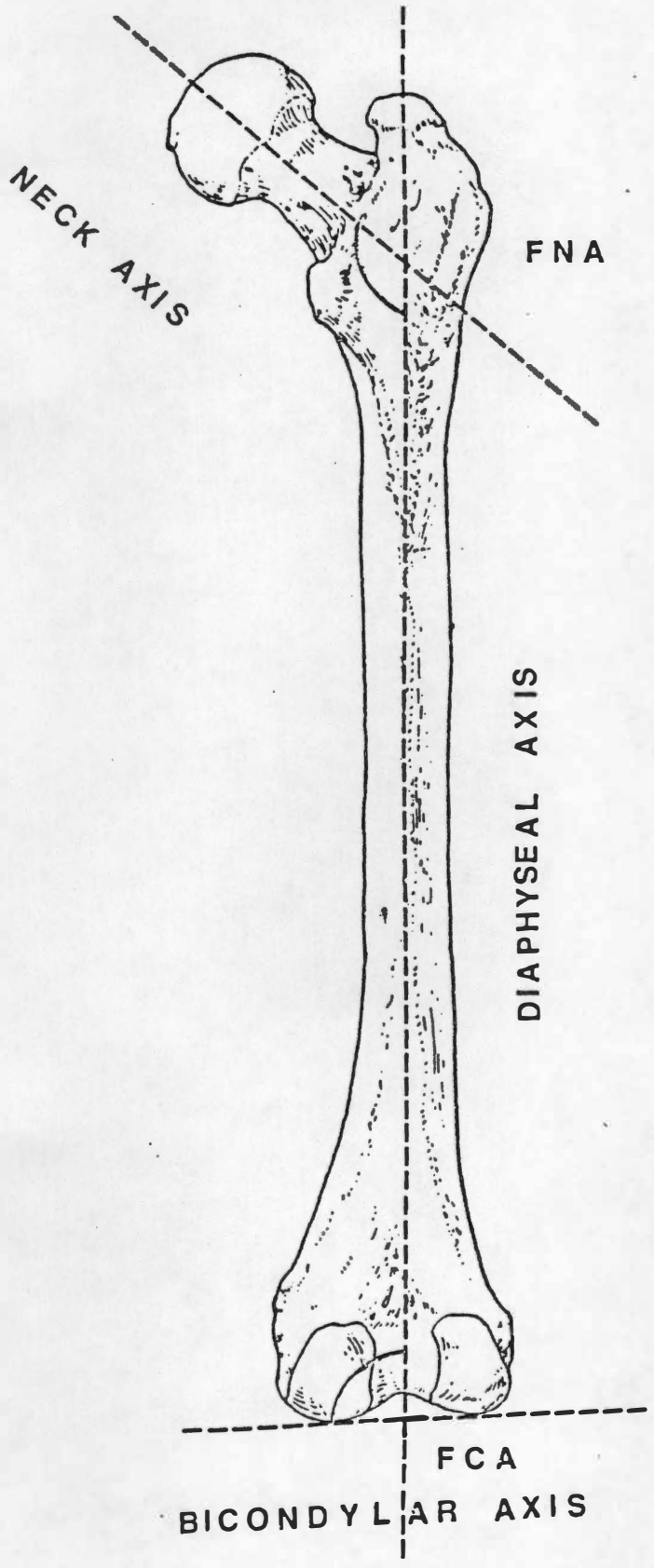


Figure 3. Angles of the Femur.

4. Anterio-Posterior Robusticity and Bicondylar Angle. This component accounts for 10% of the total variation. It appears to contrast the anterio-posterior dimensions of the shaft (APS, APD) with the bicondylar angle (FCA). The relationship of the angle to the component can be seen in Figure 3. The signs indicate that the correlation is negative. As the diameters increase the angle grows more acute. This relationship is interesting in light of component 2. On this component APD and FCA were positively correlated. It would seem that there is more than one functional demand influencing the relationship between bicondylar angle and A-P diameter (APD at least).

Of the three analogous components this one is, perhaps, the most tenuous. Van Gerven (1971:55) obtains high loadings for bicondylar angle and torsion. The anterio-posterior diameters do not contribute significantly to the component, however they are negatively correlated with the bicondylar angle. Perhaps there is a correlation between torsion and A-P diameters. Such a correlation might explain why, in the absence of a measure of torsion (present analysis), APD and APS have high loadings and, when torsion is measured (Van Gerven's analysis), APD and APS have low loadings. Salient loadings for component 4 are:

APD	0.70	FCA	-0.52	APS	0.75

Tibia

Two principal components with eigenvalues greater than 1.0 were extracted from the pooled within-groups correlation matrix. They account for 67% of the total variation. Appendix Tables C-5 and D-5 are the correlation and rotated principal component matrices, respectively.

Final communality estimates for the majority of the variables are disappointingly low. The values are 0.68, 0.71, 0.70, 0.54, 0.51, and 0,85 for TML, BPE, BDE, APN, MLM and NFL, respectively. The reason for the low correlations is not clear. The measurements are clearly defined and readily replicated.

The lowest salient loading for any single component, regardless of sign, is 0.69 for TML on component 2. All loadings greater than or equal to 0.69 are considered in the interpretation of the components.

1. General Robusticity. Forty-two percent of the total variation is accounted for by this component. It clearly describes general robusticity. Width of the proximal and distal epiphyses (BPE and BDE, respectively) have the highest loadings. The anterio-posterior and medio-lateral diameters of the shaft at the level of the nutrient foramen (APN and MLM, respectively) have slightly lower loadings. All loadings are positive indicating that, in general, individuals with robust epiphyses have robust shafts. Salient loadings are:

BPE	0.80	APN	0.73
BDE	0.80	MLM	0.70

2. Position of the Nutrient Foramen and Tibial Length. This component measures the position of the nutrient foramen with respect to the proximal epiphysis, and accounts for 25% of the total variation. The highest loading is on the position of the nutrient foramen (NFL). Maximum length is the only other significant loading. The correlation between the two is positive indicating, as would be expected, that the further the foramen is from the proximal end the longer the tibia is. However, the strength of the correlation is not as strong as one might expect. The interpretation of this component is clouded somewhat by the interpretation of component 12 of the All Bones analysis (see below). It too is concerned with the positioning of the nutrient foramen. However, unlike the present component, nutrient foramen position is negatively correlated with the diameters of the shaft at the level of the foramen (APN and MLM). TML does not load significantly on this component. This problem is discussed in more detail in Section VI.

Salient loadings for component 2 are:

TML	0.69	NFL	0.92

All Bones Combined

Twelve principal components with eigenvalues greater than 1.0 were extracted from the pooled within-groups

correlation matrix. They account for 78% of the total variation. Appendix Tables C-6 and D-6 are the correlation and rotated principal component matrices, respectively.

In general, final communality estimates are high. Seven variables have moderate values: 0.59, 0.55, 0.60, 0.52, 0.62, 0.60, and 0.60 for BOP, MBO, WOP, GCB, MCS, ULC, and FCA, respectively. Low values here are not unexpected since many of these variables also have low values in their respective individual bone analyses.

While the present component structure defines relationships between unarticulated skeletal elements some general comparisons can be made with studies of body measurements of living samples (e.g., Tanner 1964; Skibinska 1977). After all, many of the body measurements include, either directly or indirectly, dimensions of the skeleton. The majority of such studies, depending upon the variables chosen, are able to identify certain broad structural elements. Usually, they include limb length, robusticity of the extremities, and body breadth. Within a broad interpretational context some of these same structural elements are identified by the present analysis, especially limb length and breadth dimensions. The need for stressing caution when making such comparisons can not be overstated. Not only are the variable sets and the nature of the samples different but, the analytical techniques are usually different also. The

majority of the body measurement analyses employ factor analysis rather than principal components (see Zegura 1978a for a lucid layman's discussion of the differences between the two approaches and the confusion that has resulted from not knowing these differences). However, the two approaches may still produce similar results (cf. Key 1982 and Howells 1973).

The lowest salient loading, regardless of sign, is 0.38 for CML and ORL on component 1 and APS on component 12. All loadings greater than or equal to 0.38 are considered in the interpretation of the components.

1. Articular Area Robusticity. This component accounts for 18% of the total variation. It clearly defines the robusticity or size (particularly breadth) of articular surfaces. Almost all of the measures of articular areas have high loadings. An examination of the loadings, in order of magnitude, reveals that while all loadings are positive the loadings for the lower limbs, in general, are more highly correlated with the component.

Only two nonarticular area variables have significant loadings on this component; maximum clavicle length (CML) and the medio-lateral diameter of the tibial shaft at the level of the nutrient foramen (MLM). The latter is difficult to interpret but, the former is possibly of interest. The clavicle, more so than the long bones, adds

to the transverse diameter of the body. Its significant loading here makes sense when it is realized that this component measures an element of body breadth in much the same way as do the various breadth factors of the body measurement studies (e.g., Skibinska's, 1977:76, factor 3 has high loadings for epicondylar measurements as well as a chest breadth measurement).

Salient loadings for component 1 are:

BUE	0.76	HHD	0.79	FEB	0.87	RDH	0.48
BPE	0.84	APL	0.79	BCB	0.71	GCH	0.64
BDE	0.81	OCL	0.39	ULC	0.56	ORL	0.38
MDH	0.70	APM	0.72	VDN	0.53	VHD	0.78
EBR	0.53	GCB	0.50	CML	0.38		

2. Limb Length. This component accounts for 18% of the total variation. It measures general limb length and thus, can be thought of as corresponding to the similar limb length factors produced by the various studies of body measurements (e.g., Skibinska's 1977:75, factor 1). Every long bone length has a high loading on this component. Less important loadings are on clavicle length (CML), position of the tibial nutrient foramen (NFL), length of the lateral border of the scapula (GIL), vertical diameter of the femoral neck (VDN), capito-collar length (CCL), anterio-posterior diameter of the femur mid-shaft (APS) and the

length of the scapular spine (SLS). All correlations are positive, as would be expected given the results of the various studies of stature estimation that find similar high positive correlations among the lengths of long bones (e.g., Trotter and Gleser 1952, 1958; Dupertuis and Hadden 1951; Hrdlicka 1939; Keen 1953; Stewart 1968).

Salient loadings for component 2 are:

HML	0.76	TML	0.88	GIL	0.49	FOL	0.84
RML	0.88	APS	0.41	UPL	0.89	NFL	0.47
UML	0.87	BML	0.88	VDN	0.46	SLS	0.41
FML	0.83	CML	0.44	CCL	0.45	FTL	0.84

3. Vertebral Border Angle. This component accounts for 6% of the total variation. It is identical in variables included and interpretation to component 2 of the Scapula principal component analysis. Therefore, rather than repeat this interpretation the reader is directed to the original discussion on page 29.

It is disappointing that neither this component nor any of the following scapular components include nonscapular elements of the pectoral girdle (i.e., humerus and clavicle). The isolation of skeletal elements is a major feature of the All Bones Combined analysis; other than the components of general size and robusticity only component 8 includes measurements from more than one bone (see pp. 52-53

for a discussion of this component). This problem is addressed more fully in Section VI.

Since the salient loadings of the present component are unique to this component they are given:

SSL	0.63	CSA	0.96
SSA	0.81	MSA	-0.91

4. Breadth and Shape of the Scapular Body. This component accounts for 5% of the total variation. It is identical in variables included and interpretation to component 3 of the Scapula principal component analysis. Again the reader is directed to the original discussion on page 32.

Since the salient loadings of the present component are unique to this component, they are given:

SMB	0.83	ISA	0.86
SLS	0.65	LSA	-0.36

5. Shaft Size. This component accounts for 7% of the total variation. The meaning of this component is somewhat unclear. The highest loadings are on measures of humeral shaft size (LCS, MDS, MDM). Moderate loadings are obtained for the anterio-posterior diameters of the femur (APD, APS), the maximum circumference of the radial neck (MCS) and the least circumference of the ulnar shaft (ULC). While these

variables are all measures of shaft size they are by no means a complete list of all such variables included in the present analysis. To be a more definite indicator of a structural dimension of shaft size there should be more shaft size variables with significant loadings on this component.

All signs are positive, and the salient loadings are:

MDS	0.74	MCS	0.45
MDM	0.73	APS	0.43
APD	0.61	ULC	0.41
LCS	0.43		

6. Length and Tapering of the Scapular Body. This component accounts for 5% of the total variation. It measures the length of the scapula and its relationship to the shape of the scapular body. While the present component is similar to component 4 of the Scapula analysis there are differences. The present component places more emphasis on measures of length. The three main measures of body length (SML, ISL, GIL) have the highest loadings. In this respect it has elements of component 1 of the Scapula analysis which defined general scapular body size. However, it does not contain component 1's elements of breadth (SMB, SLS). It is interesting that of the four Scapula analysis' components, three are repeated in identical form in the present

analysis. Only component 1 does not have a direct counterpart. It is suspected that the present component is an indirect counterpart, accounting for the most important element, length, while breadth has been absorbed by the other scapular components (3, 4, and 9) and component 2 (limb length which contains SLS).

The shape element that is included on this component is contained in the significant loading for the inferior border angle (ISA). The relationship of the angle to the component can be seen in Figure 2 (p. 30). This component contrasts the angle with the measures of length. As the body lengthens the inferior angle grows more acute. This pattern produces a long tapered scapular body; the reverse would produce a short, squat body.

Two other variables have significant loadings, glenoid cavity height (GCH), which is associated with overall body length, and the unexplainable epicondylar breadth of the humerus (EBR).

Salient loadings are:

SML	0.77	GIL	0.59
ISL	0.70	ISA	-0.43
EBR	0.41	GCH	0.42

7. Femoral Condyle Angle. This component accounts for 3% of the total variation. It is clearly a measure of the

angle of the femoral condyles to the long axis of the shaft. The condylar angle (FCA) has the highest loading. Only one other variable has a significant loading on this component, capito-collar length (CCL). The relationship of the angle to the component can be seen in Figure 3 (p. 41). As capito-collar length (CCL) increases the proximal end of the femur is shifted laterally. At the distal end the condyles must remain in articulation with the tibial condyles. The net result of these competing forces is that the shaft of the femur joins the condyles at a more obtuse angle than before.

Salient loadings for component 7 are:

FCA	0.69	CCL	0.53

8. Elbow Articulation. This component accounts for 4% of the total variation. It is one of the more interesting components of the entire structure because it is the only component, other than those of general size and robusticity, that involves the interaction of two bones. This component measure the size of the elbow articulation. The highest loadings are on the measures of length of the olecranon articular areas (ORL and OCL) with a slightly lower value on the diameter of the radial head. The interpretation of this component would be more satisfying if it included other obvious dimensions of the elbow joint, such as epicondylar

breadth of the humerus (EBR) or the measures of the breadth of the olecranon process (MBO and BOP). The possible inadequacy of the latter two measurements to accurately reflect the breadth of the process may explain their nonsignificant loadings.

The correlations between the variables are all positive indicating that if one element of the elbow joint is large the other elements will be too.

Salient loadings are:

RDH	0.53	OCL	0.76	ORL	0.71

9. Length and Shape of the Scapular Body. This component accounts for 5% of the total variation. This component is identical to component 4 of the Scapula analysis. Therefore, rather than repeat this interpretation the reader is directed to the original discussion on page 32.

Since the salient loadings of the present component are unique to this component they are given:

ISL	-0.44	VSA	0.88
GIL	0.39	SSA	-0.41
LSA	-0.82		

10. Femoral Neck Angle. This component accounts for 4% of the total variation. This component is similar to

component 2 of the Femur analysis (see pp. 39-40) since it too measures the shape of the proximal femur. That it differs from component 2 is reflected in the decision to assign the component a different name. The present component lacks the high loadings on APD, CCL, and FCA, thus it is less complex in its interpretation.

The highest loading is on the femoral neck angle (FNA) with slightly lower loadings on the medio-lateral diameters of the shaft (MLD, MLS). The component contrasts the diameters with the neck angle. The relationship of the angle to the component can be seen in Figure 3 (p. 41). As the shaft "flattens" as a result of increased M-L diameters, the neck angle grows more acute.

Salient loadings are:

MLD	0.54	FNA	-0.82	MLS	0.60

11. Olecranon Process Size. This component accounts for 3% of the total variation. It clearly measures the size of the olecranon process as defined by the width (WOP) and breadth (MBO, BOP) of the process. This is an odd component; one must wonder why these variables do not correlate with component 8, elbow articulation, since the olecranon process is an integral feature of the joint. All correlations are positive.

Salient loadings are:

BOP	0.45	WOP	0.60	MBO	0.53

12. Position of the Tibial Nutrient Foramen. This last component accounts for 3% of the total variation. It appears to measure the position of the tibial nutrient foramen. The highest loading is on the length of the foramen from the proximal epiphysis (NFL). The diameters of the shaft at the level of the nutrient foramen (APN, MLM) also have significant loadings. Contrary to component 2 of the Tibia analysis (see p. 44), the position of the nutrient foramen would seem to depend upon the diameter of the shaft rather than the length of the tibia. The nature of the relationship is negative, the larger the shaft the closer is the nutrient foramen to the proximal epiphysis. The significant loading for the A-P diameter of the midshaft of the femur supports the observations of Miller and Purkey (1980) to the extent that the diameter reflects the area distribution of the shaft. They observe (1980:7) that the area distribution of the lower extremities uniformly decreases from the level of the hip to the ankle, and that this tapering of bony material "is an effective method of distribution to optimize strength-weight ratios and aid in efficient ambulation."

Salient loadings are:

APS	0.38	MLM	0.41
APN	0.49	NFL	-0.60

Multiple Analysis of Variance

Scapula

A MANOVA was calculated with the component scores of the scapula to test for systematic group, sex, and interaction differences. While significant results were obtained for the group and sex effects, the interaction effect was found to be nonsignificant. Table 4 presents the results of the overall tests of significance for the effects.

Table 4. Scapula: Overall MANOVA Tests of Significance.

Effect	Wilk's Criterion	F	D.F.	PR>F
Group	0.7400	1.71	48, 1011	0.0021
Sex	0.6162	40.79	4, 262	0.0001
Interaction	0.8963	0.73	40, 995	0.8941

The results of the ANOVAs are presented in Table 5. These results reveal that component 1 contributes to the sex heterogeneity and component 4 contribute to the group heterogeneity. Sex differences in the size of the scapula (component 1) are not unexpected. The significance of the

Table 5. Scapula: ANOVAs for Group, Sex and Interaction Effects.

Component	Source	Sum of Squares	F
1	Model	456.36	20.10****
	Group	18.96	1.60
	Sex	161.66	163.80***
	Interaction	13.25	1.34
	Error	261.54	1.34
2	Model	21.60	0.95
	Group	17.23	1.46
	Sex	0.22	0.22
	Interaction	3.97	0.40
	Error	261.46	
3	Model	32.84	1.45
	Group	18.01	1.53
	Sex	0.25	0.25
	Interaction	9.90	1.01
	Error	260.08	
4	Model	40.62	1.81*
	Group	28.44	2.43***
	Sex	1.33	1.36
	Interaction	2.10	0.21
	Error	258.91	

Note: Sums of Squares for Group, Sex and Interaction are Type IV. Degrees of freedom for Model, Error, Group, Sex and Interaction are 23, 265, 12, 1 and 10; respectively.

*$p < 0.05$.

***$p < 0.005$.

****$p < 0.0001$.

group heterogeneity along component 4 is unclear. An examination of the group means for component 4 (Table 6) plotted against median date (Figure 4) and latitude (Figure 5) for each group does not reveal any obvious pattern, either temporally or spatially.

Humerus

A MANOVA was calculated with the component scores of the humerus to test for systematic group, sex, and interaction differences. While significant results were obtained for the sex effect, the group and interaction effects were found to be nonsignificant. Table 7 presents the overall tests of significance for the effects.

The results of the ANOVAs are presented in Table 8. These results reveal that both components contribute to the sex heterogeneity. Sex differences in the size (component 1) and robusticity (component 2) of the humerus are not unexpected.

Ulna

A MANOVA was calculated with the component scores of the ulna to test for systematic group, sex, and interaction differences. While significant results were obtained for the group and sex effects, the interaction effect was found to be nonsignificant. The significant results obtained for the group effect are unexpected given the possibly

Table 6. Group Means for Scapula Component 4.

Group	Mean
Oahe Village (39HU2)	2.011
Four Bear (39DW2)	0.389
Mobridge F2 (39WW1)	0.340
Sully D (39SL4)	0.151
Larson (39WW2)	0.071
Sully E (39SL4)	-0.010
Mobridge F1 (39WW1)	-0.080
Rygh (39CA4)	-0.198
Leavenworth (39CO9)	-0.322
Sully A (39SL4)	-0.559
Stony Point (39ST235)	-0.584
Swan Creek (39WW7)	-0.597
Leavitt (39ST215)	-1.181

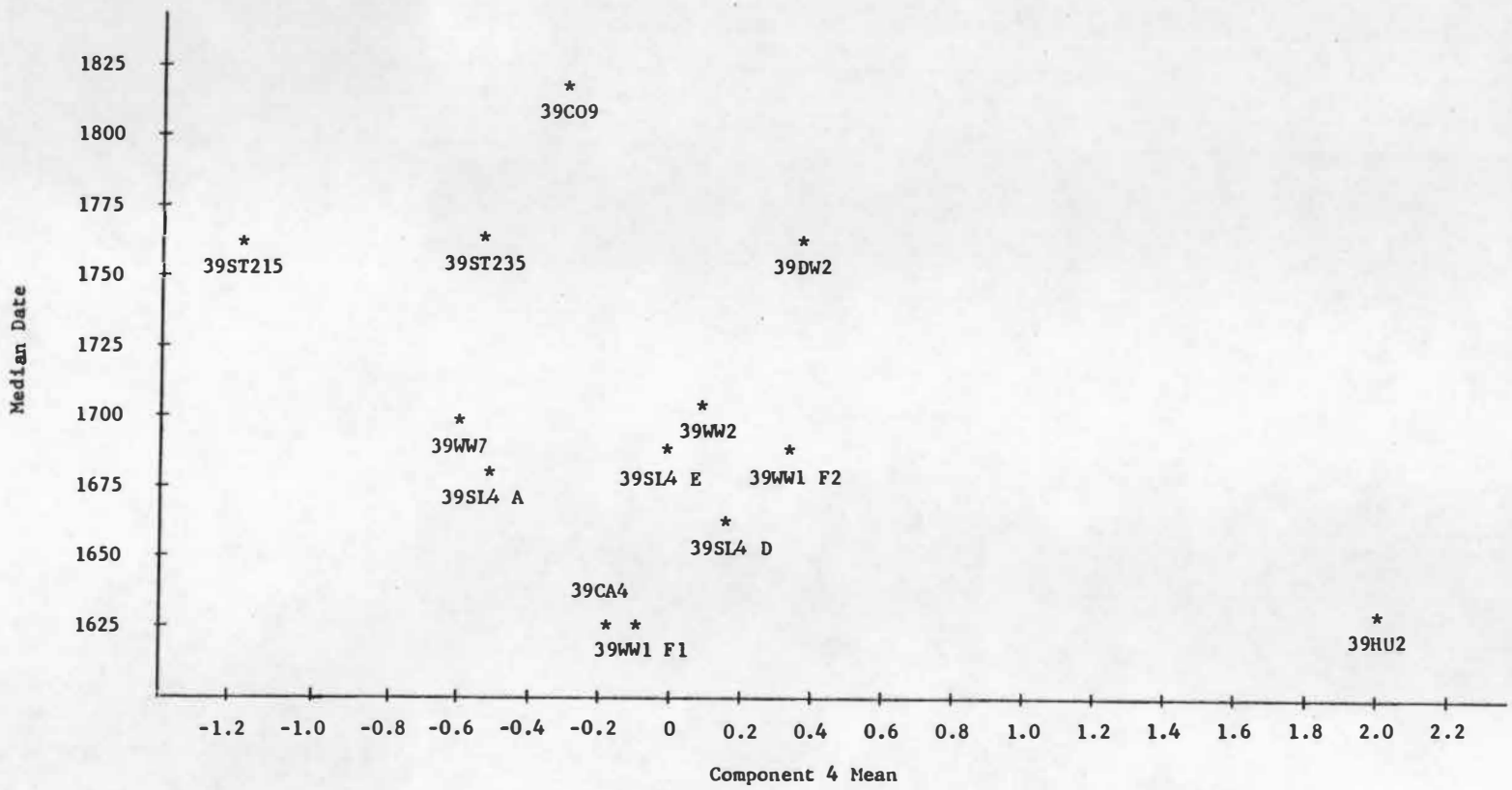


Figure 4. Scapula: Plot of Component 4 Mean Scores and Median Date.

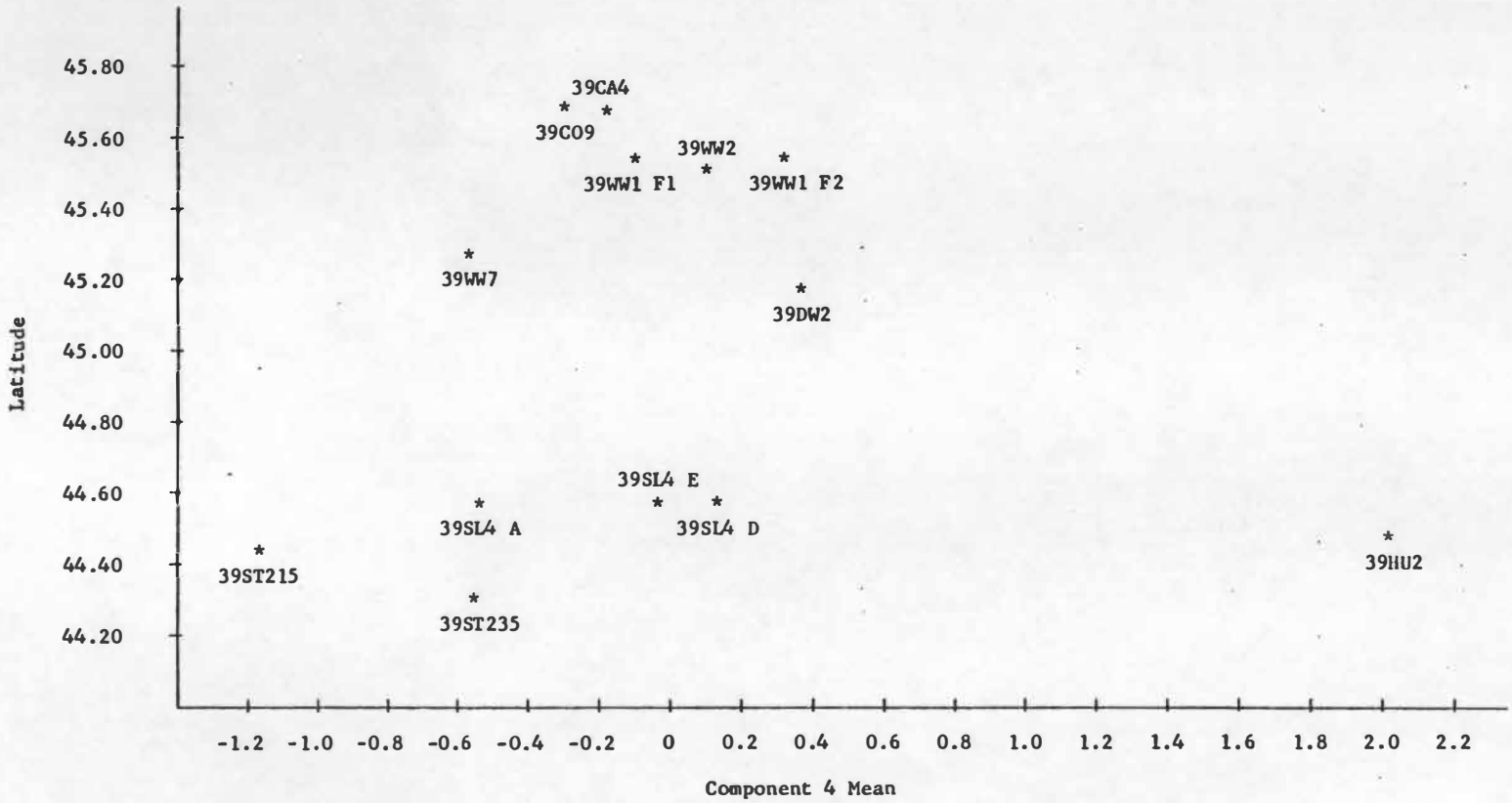


Figure 5. Scapula: Plot of Component 4 Mean Scores and Latitude.

Table 7. Humerus: Overall MANOVA Tests of Significance.

Effect	Wilk's Criterion	F	D.F.	PR>F
Group	0.9392	1.13	24, 854	0.2976
Sex	0.6453	117.36	2, 427	0.0001
Interaction	0.9568	0.79	24, 854	0.7465

Table 8. Humerus: ANOVAs for Group, Sex and Interaction Effects.

Component	Source	Sum of Squares	F
1	Model	814.24	31.44****
	Group	15.89	1.28
	Sex	231.55	223.49****
	Interaction	10.35	0.83
	Error	443.44	
2	Model	43.54	1.73**
	Group	11.90	0.98
	Sex	9.39	9.31***
	Interaction	9.57	0.79
	Error	431.73	

Note: Sums of Squares for Group, Sex and Interaction are Type IV. Degrees of freedom for Model, Error, Group, Sex and Interaction are 25, 428, 12, 1 and 12; respectively.

**p < 0.01.

***p < 0.005.

****p < 0.0001.

unreliable nature of several of the ulnar measurements. Table 9 presents the results of the overall tests of significance for the effects.

Table 9. Ulna: Overall MANOVA Tests of Significance.

Effect	Wilk's Criterion	F	D.F.	PR>F
Group	0.8654	1.53	36, 1096	0.0247
Sex	0.7292	45.93	3, 371	0.0001
Interaction	0.9316	0.74	36, 1096	0.8699

The results of the ANOVAs are presented in Table 10. These results reveal that all three components contribute to sex heterogeneity. Sex differences due to robusticity, shaft length and size of the articular surface are not surprising. The results also indicate that component 3 is responsible for the group heterogeneity. The significance of these group differences is unclear. Sully D appears to have unusually large articular surfaces, large enough to significantly separate Sully D from the other 12 groups by means of a Duncan's multiple range posthoc test (d.f. = 373, mean square error = 0.973, PR > 0.05).

A further examination of the group means (Table 11) plotted against median date (Figure 6) and latitude (Figure 7), for each group, does not reveal any obvious pattern, either temporally or spatially.

Table 10. Ulna: ANOVAs for Group, Sex and Interaction Effects.

Component	Source	Sum of Squares	F
1	Model	78.64	3.24****
	Group	8.07	0.69
	Sex	25.16	25.91****
	Interaction	15.29	1.31
	Error	362.19	
2	Model	300.52	12.47****
	Group	7.98	0.69
	Sex	83.52	86.64****
	Interaction	2.91	0.25
	Error	359.57	
3	Model	132.00	5.43****
	Group	38.40	3.29***
	Sex	25.89	26.61****
	Interaction	7.83	0.67
	Error	362.91	

Note: Sums of Squares for Group, Sex and Interaction are Type IV. Degrees of freedom for Model, Error, Group, Sex and Interaction are 25, 373, 12, 1 and 12; respectively.

***$p < 0.005$.

****$p < 0.0001$.

Table 11. Group Means for Ulna Component 3.

Group	Mean
Sully D (39SL4)	0.953
Sully E (39SL4)	0.403
Stony Point (39ST235)	0.243
Oahe Village (39HU2)	0.081
Leavenworth (39CO9)	0.015
Larson (39WW2)	0.004
Mobridge F1 (39WW1)	-0.036
Mobridge F2 (39WW1)	-0.184
Sully A (39SL4)	-0.229
Four Bear (39DW2)	-0.281
Leavitt (39ST215)	-0.389
Rygh (39CA4)	-0.421
Swan Creek (39WW7)	-0.529

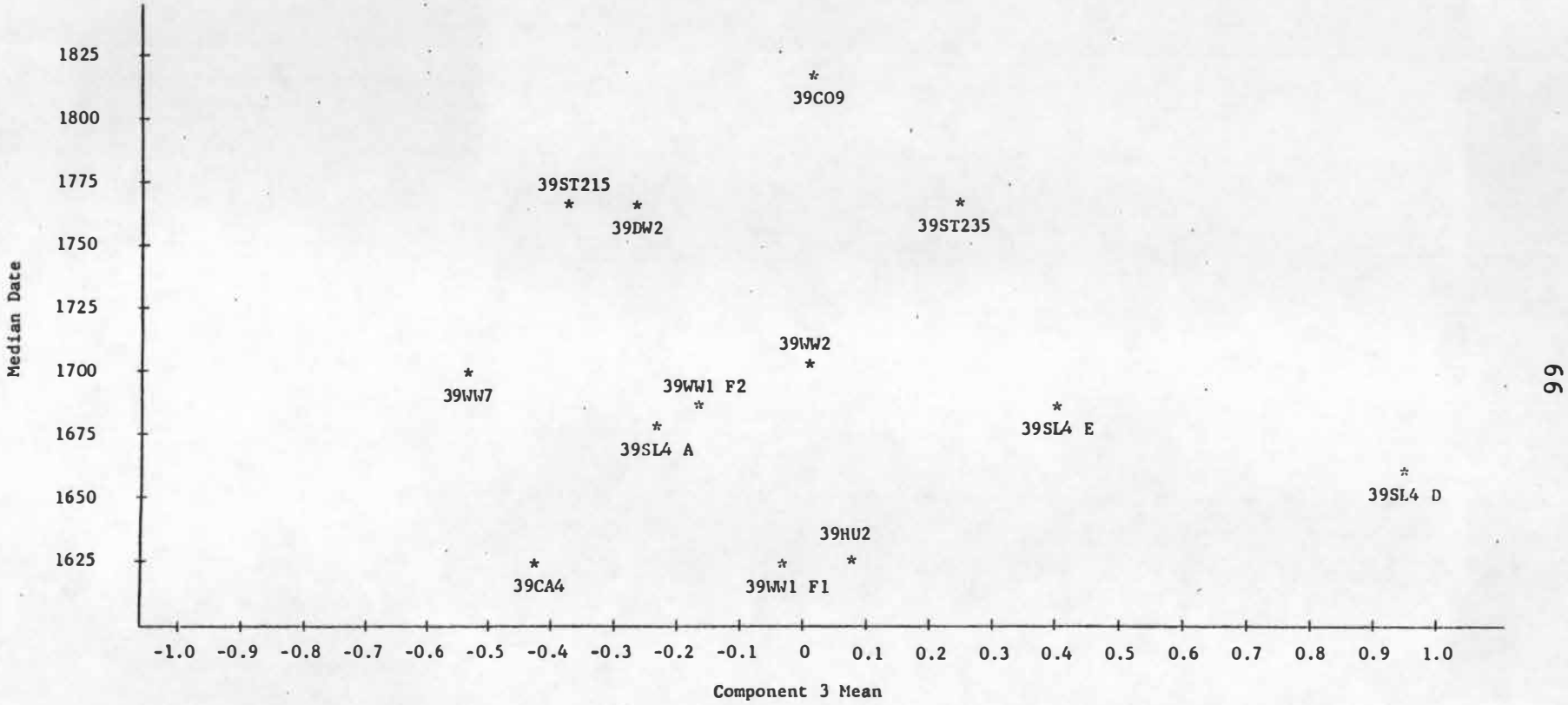


Figure 6. Ulna: Plot of Component 3 Mean Scores and Median Date.

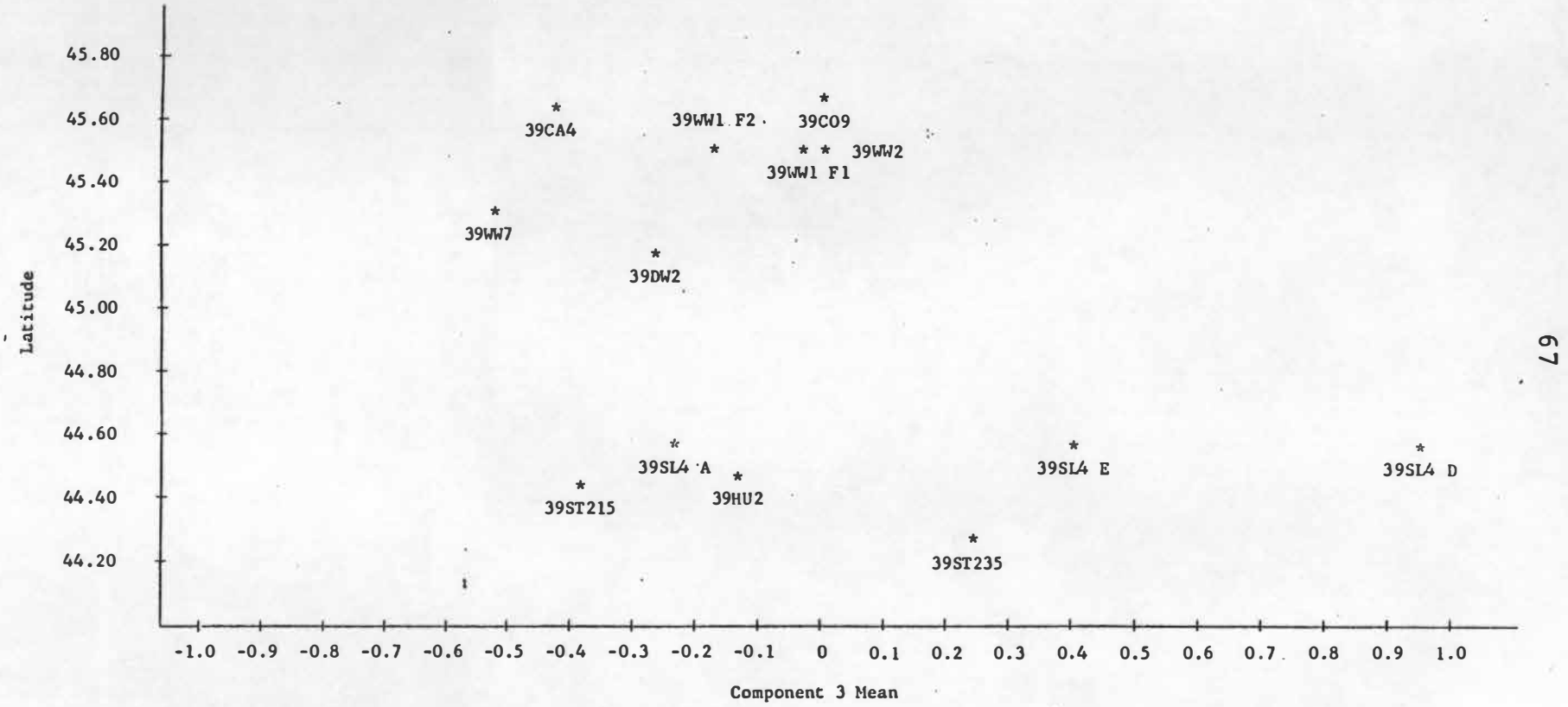


Figure 7. Ulna: Plot of Component 3 Mean Scores and Latitude.

Femur

A MANOVA was calculated with the component scores of the femur to test for systematic group, sex and interaction differences. While significant results were obtained for the sex effect, the group and interaction effects were found to be nonsignificant. Table 12 presents the results of the overall tests of significance for the effects.

Table 12. Femur: Overall MANOVA Tests of Significance.

Effect	Wilk's Criterion	F	D.F.	PR>F
Group	0.8556	1.24	48, 1442	0.1266
Sex	0.5366	80.74	4, 374	0.0001
Interaction	0.9022	0.98	40, 1420	0.5119

The results of the ANOVAs are presented in Table 13. These results reveal that all four components contribute to the sex heterogeneity with component 2 contributing the least. Sex differences in general size (component 1) and length (component 3) are not unexpected given the known data on sexual dimorphism. Sex differences in the shape of the proximal femur (component 2) and bicondylar angle (component 4) are most probably due to the demands of childbirth placed upon the female pelvis (see Section VI for a more detailed discussion of this relationship).

Table 13. Femur: ANOVAs for Group, Sex and Interaction Effects.

Component	Source	Sum of Squares	F
1	Model	521.77	23.81****
	Group	10.41	0.89
	Sex	179.74	183.69****
	Interaction	6.91	0.71
	Error	368.89	
2	Model	30.93	1.35
	Group	12.71	1.07
	Sex	7.48	7.52**
	Interaction	10.67	1.07
	Error	374.72	
3	Model	120.26	5.25****
	Group	8.83	0.74
	Sex	44.75	44.91****
	Interaction	11.29	1.13
	Error	375.65	
4	Model	267.02	11.75****
	Group	27.88	2.35**
	Sex	85.62	86.69****
	Interaction	10.18	1.03
	Error	372.38	

Note: Sums of Squares for Group, Sex and Interaction are Type IV. Degrees of freedom for Model, Error, Group, Sex and Interaction are 23, 377, 12, 1 and 10; respectively.

**p < 0.01.

****p < 0.0001.

Only component 4 produces any significant group dispersion but, it is not enough to produce an overall significant group effect.

Tibia

A MANOVA was calculated with the component scores of the tibia to test for systematic group, sex, and interaction differences. While significant results were obtained for the sex effect, the group and interaction effects were found to be nonsignificant. The results of the overall tests of significance are presented in Table 14.

Table 14. Tibia: Overall MANOVA Tests of Significance.

Effect	Wilk's Criterion	F	D.F.	PR>F
Group	0.9340	1.18	24, 816	0.2513
Sex	0.5789	148.40	2, 408	0.0001
Interaction	0.9264	1.33	24, 816	0.1365

The results of the ANOVAs are presented in Table 15. These results indicate that both components contribute to sex heterogeneity. Sex differences in robusticity and length are not unexpected.

All Bones Combined

A MANOVA was calculated with the component scores of all the bones combined to test for systematic group, sex and

Table 15. Tibia: ANOVAs for Group, Sex and Interaction Effects.

Component	Source	Sum of Squares	F
1	Model	643.40	26.60****
	Group	9.26	0.80
	Sex	201.67	208.42****
	Interaction	12.52	1.08
	Error	395.74	
2	Model	236.46	9.19****
	Group	19.68	1.59
	Sex	90.46	87.86****
	Interaction	19.53	1.58
	Error	421.09	

Note: Sums of Squares for Group, Sex and Interaction are Type IV. Degrees of freedom for Model, Error, Group, Sex and Interaction are 25, 409, 12, 1 and 12; respectively.

****$p < 0.0001$.

interaction differences. While significant results were obtained for the sex effect the group and interaction effects were found to be nonsignificant. The results of the overall tests of significance are presented in Table 16.

Table 16. All Bones Combined: Overall MANOVA Tests of Significance.

Effect	Wilk's Criterion	F	D.F.	PR>F
Group	0.4270	0.90	132, 1080	0.7841
Sex	0.4630	12.56	12, 130	0.0001
Interaction	0.6102	0.70	96, 885	0.9852

The results of the ANOVAs are presented in Table 17. These results reveal that components 1, 2, 3, 6, 7, and 10 contribute, almost equally, to the sex heterogeneity. Sex differences in the robusticity of the articular areas (component 1), limb length (component 2), and length of the scapular body (component 6) are not unexpected. Elements of components 7 and 10 (condylar and neck angles of the femur, respectively) have already been shown to contribute to sex heterogeneity (see Femur MANOVA, pp. 68-70). It is interesting that component 3 (vertebral border angles) produces a significant result here but, not in the Scapula MANOVA (see pp. 56-58).

Only component 5 (shaft size) produces a significant test for group effect but, it is not enough to produce an

Table 17. All Bones Combined: ANOVAs for Group, Sex and Interaction Effects.

Component	Source	Sum of Squares	F
1	Model	209.17	9.97****
	Group	3.68	0.32
	Sex	75.36	71.80****
	Interaction	5.57	0.66
	Error	147.96	
2	Model	113.11	5.10****
	Group	12.67	1.04
	Sex	44.32	39.98****
	Interaction	9.79	1.10
	Error	156.28	
3	Model	10.46	0.54
	Group	2.82	0.26
	Sex	2.43	2.50
	Interaction	4.06	0.52
	Error	136.84	
4	Model	21.44	1.23
	Group	9.99	1.04
	Sex	0.01	0.00
	Interaction	5.44	0.78
	Error	122.62	
5	Model	28.34	1.42
	Group	20.21	1.85
	Sex	0.21	0.21
	Interaction	9.23	1.16
	Error	140.39	
6	Model	54.65	2.93****
	Group	12.82	1.25
	Sex	12.06	12.92***
	Interaction	8.28	1.11
	Error	131.58	
7	Model	21.10	1.29
	Group	7.15	0.80
	Sex	5.98	7.32**
	Interaction	2.93	0.45
	Error	115.08	

Table 17 (continued)

Component	Source	Sum of Squares	F
8	Model	8.38	0.44
	Group	5.45	0.52
	Sex	0.36	0.38
	Interaction	4.25	0.56
	Error	134.39	
9	Model	20.13	0.97
	Group	16.55	1.45
	Sex	0.19	0.18
	Interaction	2.83	0.34
	Error	146.04	
10	Model	35.48	1.82*
	Group	8.20	0.77
	Sex	13.40	13.77***
	Interaction	4.21	0.54
	Error	137.18	
11	Model	16.80	0.90
	Group	7.51	0.73
	Sex	0.06	0.06
	Interaction	6.34	0.85
	Error	132.25	
12	Model	28.93	1.51
	Group	18.40	1.75
	Sex	2.71	2.84
	Interaction	6.68	0.87
	Error	134.66	

Note: Sums of Squares for Group, Sex and Interaction are Type IV. Degrees of freedom for Model, Error, Group, Sex and Interaction are 20, 141, 11, 1 and 8; respectively.

*p < 0.05.

**p < 0.01

***p < 0.005.

****p < 0.0001.

overall significant group effect. It is somewhat puzzling that components 7 (femoral condyle angle) and 9 (length and shape of the scapular body) do not produce significant results here since they do so for the Femur (component 4) and Scapula (component 4) MANOVA analyses.

VI. DISCUSSION AND CONCLUSIONS

The purpose of this chapter is to interpret the results as they apply to the goals stated at the outset: to identify intrapopulation patterns of postcranial variation and to determine the relationship of this variation to postcranial interpopulation variation. Also included in this chapter are discussions of certain associated questions, also stated at the outset. These questions concern: the level of congruence between Arikara craniometric and postcraniometric studies for identifying population differences, changes in the patterns of postcranial sexual dimorphism, and aspects of the functional morphology of the postcranial skeleton. The chapter is divided into three sections and a summary:

1. A discussion of the within-group variation as represented by the results of the rotated principal component analysis. The components are discussed in terms of the morphology they represent, with special emphasis on functional morphology.

2. A discussion of how the within-group variation relates to the between-group variation. This section focuses on the results of the several MANOVAs. To paraphrase Howells (1973:146), the interpretation of the results centers on whether or not group differences in postcranial shape are based upon traits which have a common

ground of individual genetic variation within all groups. Also included in this section is an evaluation of the level of congruence between the results obtained by craniometric analyses of the Arikara and the present postcraniometric analysis.

3. A discussion of the pattern of postcranial sexual dimorphism of the Arikara. This discussion focuses on the contribution the present study can make to the debate on the controlling factors of sexual dimorphism in human populations.

Within-Group Variation

One of the stated goals of the present analysis is to identify patterns of intrapopulation (within-group) variation. Principal component analysis, a multivariate statistical procedure, was chosen to define these patterns of variation. Six component analyses were carried out. The results obtained are readily interpretable in morphological terms. However, the production of interpretable components does not automatically confer biological reality upon them. Several authors (e.g, Corruccini 1978; Zegura 1978a) have recommended that in order to support the biological reality of the component interpretations the components should be equated with the original morphology they supposedly represent. The central question is: Do the component interpretations correspond to what is known about the

functional morphology of the bones they are representing? For the majority of the interpretations of the present analysis this would appear to be true. This is most clearly demonstrated in the analyses of the femur and all bones combined (see Section V).

As discussed in Section V the present analysis of the femur has several features in common with Van Gerven's (1971) femoral analysis. This fact in itself lends support to the biological reality of the interpretations. Even though the variable sets and methodologies differ between the two analyses, similar component patterns are produced. Component 1 of both analyses is interpreted as a measure of general femoral size. The work of Lovejoy and Heipel (1970), Lovejoy et al. (1973), Hirsch and Frankel (1960), Jolicoeur (1963), Scott (1957), and Trotter and Gleser (1952, 1958) dealing with the functional morphology of the femur supports this interpretation.

Lovejoy and Heipel (1970) and Lovejoy et al. (1973) discuss the direct relationship between body weight and femoral head size in hominids. In addition to supporting Lovejoy and associates, the work of Hirsch and Frankel (1960) experimentally demonstrates a relationship between body weight and femoral neck length and greater trochanter size (the measure of the latter is not included in the present analysis). Jolicoeur (1963), working with land

vertebrates, suggests that the width of the distal end of the femur is influenced by muscular development (thus body size and weight) and is therefore a reliable indicator of general robusticity. Jolicoeur (1963) and Scott (1957) suggest that there exists a direct relationship between femur shaft diameter and the shaft's weight bearing capabilities. Finally, the positive correlation between stature and femur length has been well demonstrated by Trotter and Gleser (1952, 1958). The general size-related features just described all have high loadings on component 1 of the present analysis thus, justifying an interpretation of general size.

Component 2 of both analyses (Van Gerven's and the present's) is interpreted as shape of the proximal femur. The most important loadings are on the femoral neck angle (FNA), neck length (CCL), medio-lateral shaft diameters (MLD, MLS), and in Van Gerven's analysis only, torsion (torsion was not measured in the present analysis). Van Gerven's analysis reveals that femoral neck and torsion angles are positively correlated and that both are negatively correlated with neck length and medio-lateral shaft diameters. The present analysis also shows a negative correlation between femoral neck angle and neck length and medio-lateral shaft diameters. Ljunggren (1975) demonstrated that differences in long bone shaft diameters are

associated with varying degrees of torsion produced by muscular forces acting upon the shaft. The proximal end of the femur is the location of the insertions of several major muscles important in locomotion and stabilization of the hip joint. Several workers have demonstrated an association between the muscular action and weight bearing requirements in this area and femoral torsion (Dunn 1952; Durham 1915; Elftman 1945; Ingalls 1924; Kate and Roberts 1963; Kingsley 1948; Kingsley and Olmstead 1948; Rogers 1931, 1934; Stewart 1962; Vare 1974). Assuming an association between torsion and proximal femur diameters (which thus can be thought of as an indirect measure of torsion) it would appear from the relationships defined by the present analysis' component 2 that as the femoral neck and torsion (by inference) angles increase the medio-lateral shaft diameters and neck length decrease. This pattern produces a proximal femur with a large femoral neck angle, a neck that is short and is "twisted" away from the normal axis of orientation (which is, according to Vare 1974, 9.6°), and a medio-laterally flattened shaft.

Component 3 is a simple straightforward measure of length which is an obvious functional component of any long bone. The overall length, or a portion of it, acts as the biomechanical lever arm for muscular action. Changes in the length would either increase or decrease the effective lever arm.

Component 4 of both analyses (Van Gerven's and the present's) as well as component 7 of the present's All Bones analysis are interpreted as measuring the bicondylar angle. The work of Lovejoy et al. (1973) on the gait of Australopithecus provides some insight into the significance of this component. Component 7 is the clearest representation of the relationship of bicondylar angle to the total morphological pattern of the femur, therefore Lovejoy et al. (1973) results are interpreted with this component in mind. Significant loadings on this component are on the measures of capito-collar length (CCL) and bicondylar angle (FCA).

Lovejoy et al. (1973) hypothesize that Australopithecus (africanus and robustus) was optimally adapted to a bipedal gait. Two features of this optimal adaptation are of particular relevance to the present discussion; a long femoral neck and a high bicondylar angle. The femoral neck is the lateral lever arm for the abductor muscles. Its positioning in Australopithecus produces a lateral extension of the proximal end of the femur. To compensate for the lateralward movement of the proximal end the bicondylar angle is increased. The increase in the bicondylar angle has the effect of maintaining the position and orientation of the knee joint thus, retaining the placement of the feet beneath the body's center of gravity and thereby retaining an efficient bipedal gait.

However, locomotor stresses are not the only forces acting upon the morphology of the proximal femur. Hominid evolution during the Pleistocene is characterized by increasing encephalization. With increasing encephalization there is pressure for an increase in pelvic breadth. However,

> . . . there is a maximum total pelvic breadth which can be efficiently maintained in a biped . . . . In the face of increasing fetal cranial dimensions, adjustments which increased the pelvic ring but which did not increase total pelvic breadth would have been favored. (Lovejoy et al. 1973:777-778)

One feature of the response to increased encephalization was ". . . a medialward shift in the position of the femoral shaft. In this way the neck could be reduced in apparent length without concurrent reduction of the abductor lever arm" (Lovejoy et al. 1973:764-765). While the position of the knee joint would remain unchanged, the medialward shift of the proximal shaft would cause a reduction in the size of the bicondylar angle.

From the above discussion it can be seen that the stresses acting upon the relationship of the bicondylar angle to femoral neck length are multiple and complex. The nature of the correlation is positive; as neck length increases the angle grows more obtuse. Component 7 of the All Bones Combined analysis provides a clearer picture of the relationship than component 4 of the Femur analysis

because the former includes not only the measure of the bicondylar angle (FCA) but also the measure of neck length (CCL). The anterio-posterior diameters of the shaft which load significantly on component 4 may be reflecting the importance of the role of torsion to changes in the proximal femur.

The components produced by the All Bones Combined analysis also appear to reflect true morphological complexes. First, two of the femoral complexes discussed above, bicondylar angle and shape of the proximal femur, are reproduced in the All Bones Combined analysis on components 7 and 10, respectively. Second, two of the components (1 and 2) are roughly analogous to factors produced by several of the body measurement studies (e.g., Skibinska 1977; Tanner 1964).

At this point a short digression is necessary to discuss the significance of the differences in methodologies between these studies and the present analysis. The majority of the body measurement studies use factor analysis (or at least they claim to) rather than principal component analysis. There has been considerable debate over the differences between the two techniques.

Basically, principal component analysis is concerned with the explanation of variance while factor analysis attempts to reproduce a correlation matrix as closely as

possible (Zegura 1978a:152). Therefore, principal component analysis uses the complete correlation matrix, with ones in the diagonals, while factor analysis starts with a reduced correlation matrix with estimated communalities in the diagonals (Tatsuoka 1971:145). Despite the differences in methodology similar results may be obtained (cf. Key 1982 and Howells 1973). Confusion over these basic differences has also led to confusion over terminology, specifically: Should the results be termed components or factors? In a strict sense, if the analysis is carried out on a complete correlation matrix with ones in the diagonals, and when there is truncation and rotation of the matrix it is an orthogonal transformation, then the results are components. However, if a reduced correlation matrix is used or if there is truncation and an oblique rotation of the matrix then the results should be termed factors (Zegura 1978a:152).

All of this leads to confusion in the literature. Not everyone that uses the techniques is aware of the distinctions. The ideal situation would be for authors to clearly state the procedures followed. However, this is seldom done; often the correlation matrix is not provided or there is no indication of the type of rotational procedure employed. The situation is clouded further by historical considerations; both types of analyses were developed by researchers in psychology. They were primarily concerned

with isolating "factors" of psychological behavior and were therefore inclined to label all results as "factors," regardless of the actual technique used.

In the present case the component matrix is extracted from a pooled within-groups correlation matrix (with ones in the diagonals) and then rotated with the VARIMAX solution, an orthogonal transformation, rather than with the usual oblique transformations of traditional factor analysis. For these reasons the present analysis' results are referred to as components (perhaps a better term would be rotated components). Because of the lack of clarity on the part of some authors it is difficult to determine if, in the strict sense, they are discussing components or factors. For the sake of discussion the present analysis retains the terminology of the original authors; if they choose to term their results factors then the present analysis does too.

In general, the body measurement studies usually produce several factors including measures of limb length and body or limb-bone breadth. For example, Skibinska's (1977:76) body breadth factor has high loadings for measures of breadth including chest breadth, bicondylar femur breadth, and bicondylar humerus breadth. Her limb length factor (1977:75) has significant loadings on all measures of limb length. Components 1 and 2 of the present analysis are clearly analogous to these factors. Component 1 measures

articular area robusticity or, put another way, limb-bone breadth with high loadings on several measures of limb-bone breadth including bicondylar breadths of the femur and humerus and the maximum length of the clavicle which comprises a major element of chest breadth. Component 2 measures limb-bone length with salient loadings on every limb-bone length measurement. The length and breadth of the limbs have been positively correlated with body stature and weight by several authors (e.g., Trotter and Gleser 1952, 1958; Jolicoeur 1963; Skibinska 1977).

Functional morphological evidence for the support of the interpretation of the remaining components is not as clearcut. There are contradictions raised by some. For example, component 2 of the Tibia analysis and component 12 of the All Bones Combined analysis deal with the positioning of the nutrient foramen. The distance of the foramen from the proximal epiphysis (NFL) has a salient loading on both. However, on component 2 NFL is positively correlated with maximum tibial length while on component 12 it is negatively correlated with the diameters of the tibial shaft (APN, MLM). Thus, the relationship of NFL to the total morphological pattern of the tibia is defined in two different manners. Component 2 suggests that the further the nutrient foramen is from the proximal epiphysis the longer the tibia is. Component 12, on the other hand, suggests that the

further the nutrient foramen is from the proximal epiphysis the smaller the dimensions of the shaft are. An examination of the original correlation coefficients (see Table C-5, p. 150) reveals that NFL is moderately correlated with TML (0.45) and essentially uncorrelated with APN and MLM (0.03 and -0.05, respectively). These components may represent conflicting pressures influencing the positioning of the nutrient foramen. Component 2 may be a simple reflection of the preservation of proportionality of the tibial length dimensions. The meaning of component 12 is more complex. Ljunggren (1975) has suggested that the diameters of the proximal tibial shaft are influenced by the degree of torsion generated by the muscles that attach in this area. Longia et al. (1980) report that nutrient foramina are usually located on the flexor surfaces of the bone. There would appear to be some form of complex relationship between the location and activity of the musculature and the positioning of the nutrient foramen.

The present results do not permit definite conclusions to be drawn concerning the "universality" of postcranial structure. Such conclusions must await analysis of groups drawn from more diverse populations than the present samples. However, some tentative conclusions can be stated. The patterns of variation identified by the principal component analyses appear to have high degrees of biological

reality. Furthermore, the results' high level of congruence with the results of similar studies (e.g., Van Gerven 1971; Lavelle 1974; Skibinska 1977; Tanner 1964) suggest that they are identifying patterns of postcranial variation common to all populations. Again, it must be stressed that this is only a tentative conclusion and more research has to be done before more definitive statements can be made.

Further analysis also needs to be done in order to more completely explore the functional properties of the postcrania. The present analysis was not specifically designed for such an investigation although some discussion on the subject was possible. Several modifications in the research design would have to be made. Of paramount importance would be the revision of the measurement set. More measurements dealing with the dimensions of the articular surfaces need to be collected since these are the areas in which the bones interact, and would therefore contain important functional information. The fibula is a good example. Studies by Ogden (1974) on the proximal tibiofibular joint have demonstrated not only the fibula's static function as a weight bearing structure, but its dynamic function in locomotion as well. Measurements collected on the articular surfaces would reflect these functions. Finally, unreliable measurements identified by the tests of measurement error (see p. 20) need to be redefined or, failing this, eliminated.

This need is especially apparent in the measurements of the olecranon process' articular surfaces.

Among-Group Variation

The second goal of the present analysis was to determine the nature of intergroup relationships. Once these relationships are determined it should be possible to answer the question: Do the postcrania describe the same patterns of culture-historical relationships as do the crania?

The results of the several MANOVAs indicate that there is very little group heterogeneity. Only the scapular and ulnar analyses produce significant results for heterogeneity and their meaning is unclear.

The MANOVAs reveal that scapular component 4 (length and shape of the scapular body) accounts for all of the scapular group heterogeneity. An examination of the component means (Table 6, p. 59) and their plotting against median date (Figure 4, p. 60) and latitude (Figure 5, p. 61) fails to reveal any significant patterning to the variation, either temporally or spatially. The meaning of these results are complicated further because component 8 of the All Bones analysis, which is identical to Scapula component 4, does not produce significant group heterogeneity results in its MANOVA analysis.

That the ulna should produce significant group differences is surprising given the reservations concerning the accuracy and reliability of several of the ulnar measurements. Furthermore, component 3 (articular surface size), which contains the most questionable variables, accounts for all of the group heterogeneity. An examination of the component means (Table 11, p. 65) and their plotting against median date (Figure 6, p. 66) and latitude (Figure 7, p. 67) fails to reveal any significant patterning to the variation, either temporally or spatially. The significant results in this case may be nothing more than a statistical artifact with no functional relevance.

This conclusion may be supported, at least in functional terms, by Lovejoy (1975) who comments upon the adaptive significance of morphological changes in skeletal structures. He observes that:

> Isolated morphological features vary significantly more than do the mechanical attributes that are their result. To state this in other terms, the total morphological pattern and its individual elements are distinctly more variable than the total biomechanical pattern. (1975:292)

From these comments it can be concluded that even though certain morphological features of the scapula and ulna may vary the biomechanical function of the bones does not.

The failure of the present analysis to identify any significant patterning to Arikara postcranial variation is surprising given the well defined relationships produced by

the various Arikara craniometric studies (e.g., Bass 1964; Jantz 1972, 1973, 1974, 1977; Jantz et al. 1978; Key 1982; Key and Jantz 1981; Owsley and Jantz 1978). During the planning stage of the present study it was hypothesized that an analysis of Arikara postcranial variation would produce results similar to the craniometric studies. These results would either support or refute craniometric-based hypotheses concerning Arikara culture-history. For example, Key and Jantz (1981) demonstrated that intergroup differences between five Arikara sites occurred along components of facial height, transverse frontal flatness, and frontal profile flatness. They were able to show that a significant portion of the variation is temporal in nature and may be due to gene flow between the Arikara and surrounding Indian populations (the Mandan, Pawnee, and Sioux). The present analysis, on the other hand, suggests that there is very little microevolutionary change taking place, at least postcranially. The implication is that either there was no appreciable gene flow occurring and thus, the craniometric studies are misleading or the Arikara and their neighbors are homogeneous as far as the postcranial skeleton is concerned. The former can be ruled out since there is a considerable amount of evidence indicating that gene flow did occur between not only the Arikara and surrounding Indian groups but, with (in later periods) Whites as well

(Tabeau 1939; Brackenridge 1906; Bradbury 1904; Trudeau 1914; Luttig 1964). Confirmation or denial of the latter will have to wait for future analyses that would include the postcraniometrics of these groups.

While it is true that definitive confirmation or denial of the homogeneity hypothesis must await future analysis it is possible to speculate on it and other possible explanations that would explain the present results. Each possible explanation will be discussed in detail.

First, there is evidence to suggest that the postcranium, in general, is remarkably homogeneous within broad ethnic categories, suggesting that the rate of change within the postcranium has been very slow in the recent past. For example, in many important features the postcranial skeleton has remained unchanged since Neandertal times (Howell 1957; Smith 1976). This suggests the possibility that the postcranial skeleton is influenced more by functional forces than is the cranium or at least the neurocranium. While Nakata et al., 1974, and Osborne and DeGeorge, 1959, have demonstrated high heritabilities for craniometric variables Ljunggren (1975:149-155) has observed that measurements of the facial cranium are more variable than those of the neurocranium, and that the

> . . . observed differences between the neurocranium and the facial cranium reflect the function of the two parts of the cranium, the neurocranium being chiefly influenced by hereditary factors, the facial cranium also by functional factors.

Furthermore, Ljunggren (1975:149), in reporting a statistical summarization of her measurements, observes that body measurements more often show deviation from normality than do craniofacial measurements. She concludes that this is to be expected "since the external and muscular forces acting on the long bones are tremendous compared to the forces acting on the cranium" (1975:149).

Specific evidence for the support of the hypothesis of postcranial homogeneity among broad ethnic categories is provided by the work of Lavelle (1974), Huber and Jowett (1973) and Farrally and Moore (1975).

Working with femoral dimensions collected on a series of European populations, ranging from the Bronze Age to the present, Lavelle (1974:415) was able to demonstrate ". . . only limited discrimination between the samples." His discrimination was temporal in nature and showed a steady progression in the increase of femoral dimensions. However, Lavelle's groups spanned approximately 6,000 years yet he was able to demonstrate "only limited discrimination."

Huber and Jowett (1973) were concerned with the validity of using the stature reconstruction formulae of Trotter and Gleser (1958) on archaeological populations. They hypothesized that:

> Mean body proportions and the relationship of long bone lengths are known to differ among contemporary races, and there is no reason to

> believe that physical proportions of populations, of even the same genetic stock, living in different geographic regions and separated by more than a millennium, should differ any less. (1973:37)

They tested this hypothesis by comparing the proportionalities of long bones in a U.S. White sample with those of a medieval German sample. They found no significant differences in either mean length of bones or their proportionalities. They concluded that medieval Germans are strikingly similar to modern U.S. Whites, for at least these features, and that it would be acceptable to apply the U.S. White derived stature formulae to the medieval population.

Farrally and Moore (1975) tested for anatomical differences in the dimensions of the femur and tibia between Negroids and Caucasoids and their effects upon locomotion. Not surprisingly, they detected significant ethnic group differences. What is surprising and of particular relevance to the present discussion is their comments upon the variability with the Negroid sample. The Negroid sample was composed of individuals from five African archaeological sites differing greatly in space and time (the White sample was from a single archaeological population). Tests for heterogeneity revealed a surprisingly high degree of homogeneity within the Negroid sample, despite the considerable spatial and temporal differences. Their results were consistent with those of Nutter (1959, in

Farrally and Moore 1975:65) ". . . who found a similarly high level of homogeneity in a large number of measurements taken on both the upper and lower limbs of the Ibo, Haga, Somali, and Jebel Moyan series" (four of the five populations used by Farrally and Moore).

In light of the results of these studies it may not be so surprising that the Arikara postcrania are as homogeneous as they appear to be. Of the four studies discussed above the Arikara represent the most circumscribed sample in terms of time, space, and genetic affinities. If the other samples can produce "only limited" or no significant ethnic group differences then it should not be surprising when the Arikara do the same. In addition, there is no evidence to suggest that the postcranial skeleton underwent any significant morphological changes in functional terms. This despite archaeological evidence indicating an increase in female work load due to an increase in agricultural productivity during late Post-Contact Coalescent times (Lehmer and Jones 1968:88). Apparently, the Arikara were performing much the same tasks in much the same manner as they always had. Of all of the possible explanations for the failure of the present analysis to produce significance group differences this one appears to be the most probable.

Second, the unarticulated nature of the data itself may contribute to the present analysis' inability to identify

group heterogeneity. The cranium is composed of 22 bones (excluding the bones of the ear). Seldom do craniometric studies focus on single isolated bones, rather they consider the cranium to be a complex integrated whole. Understandably, Howells (1973) found that variables spanning more than one cranial element were often important contributors to group discrimination. With regards to the postcrania however, ". . . it has been the tradition that biometricians concentrate their analyses on single skeletal parts giving little heed to the joints and their function" (Howell et al. 1978:128).

The present analysis attempted to follow Howell et al. suggestion by including an analysis of all bones combined. However, this analysis failed also, perhaps because the measurements did not reflect the actual articulated nature of the bones. Unfortunately, the time and effort required to articulate a sufficient number of skeletons would be too great to make the attempt worthwhile.

Third, it may be that the statistical procedures selected for the present analysis are inappropriate for the task. Multivariate statistical procedures have come into popular use in anthropology in the past twenty years (Andrews and Williams 1973; Corruccini 1978; Zegura 1978a). Their use (and abuse) has also come under considerable criticism (Corruccini 1975, 1978; Corruccini and Ciochon

1976; Campbell 1978; Finkel 1982a). Common criticisms include the ". . . treatment of single specimens as if they are samples and the failure to separate considerations of size and shape" (Corruccini 1975:1). Some researchers suffer from a "bandwagon" effect when dealing with multivariate procedures and therefore fail to consider alternate approaches. Oxnard (1968) and Oxnard and Neely (1969) suggest the use of nonparametric methods. Corruccini (1975) discusses several studies that compare simple distance coefficients to the more complex multivariate distances and concludes that many researchers find considerable correspondence between the two. Finkel (1982a) reports that univariate tests (in this case ANOVAs) were better able to detect patterns of gene flow among several European and Middle Eastern Mediterranean populations than multivariate procedures (in this case discriminant function analysis). He therefore suggests that univariate techniques are sometimes preferable to more complex multivariate techniques. Quite often however, univariate analyses are confined to a series of t-tests performed on a large battery of measurements. The problem with this approach is that by conducting a series of related t-tests the probability of finding significant differences by chance alone is increased with each test performed. The recent work by Takahashi (1975, 1976) on the radius and humerus of the Japanese is a

good example. T-tests were calculated for each measurement (25 on the humerus, 20 on the radius) between seven populations (5 mainland Japanese, 1 Ainu, 1 Korean) by sex. A large number of the tests were significant. Of special interest is the fact that there were several significant tests between the various Japanese populations, which can be considered at least as genetically homogeneous as the Arikara. It is quite possible that many of Takahashi's results represent statistical artifacts rather than biological reality.

The valid criticisms of multivariate techniques do not however, rule out their usefulness in determining biological relationships. As Corruccini (1978:136) states, multivariate procedures offer important contributions; they are: "a) definition and standardization of comparative criteria, b) objectivity of comparison (provided the criteria are meaningful), and c) synthesis (pattern recognition)." Corruccini's (1978:136-137) concluding remark is of particular relevance:

> Of course, none of this proves that the multivariate approach is superior to the univariate or the indices, as any relative weighing of merits involves circularity of reasoning; each worker must make judgement for himself.

Such a judgment has been made for the present analysis. Principle component analysis is a useful technique for reducing a large set of measurements to a comprehensible set

of orthogonal components. MANOVA employs the best of both worlds. It employs multivariates for tests of overall heterogeneity and univariate tests (ANOVAs) for detecting differences along individual dependent variables.

In summary then, the most probable cause for the failure of the present analysis to produce significant group differences is the unusual degree of homogeneity of the postcranium within broad ethnic categories. Future analyses that would incorporate the other Amerindian groups of the Plains area or analyses of worldwide postcranial variation would undoubtably shed light on the problem.

Sexual Dimorphism

Anthropologist's interest in sexual dimorphism has grown rapidly since Greulich's (1951) pioneering study of Guanamian school children. The field was given further impetus by several studies of patterns of sexual dimorphism in Plio-Pliestocene hominids (Brace 1969, 1973; Wolpoff 1971, 1974, 1975, 1976a, 1976b; Frayer 1978, 1980; Smith 1980; Trinkaus 1980). Since then a considerable amount of data have been collected on living populations (Bielicki and Charzewki 1977; Eveleth 1975; Hiernaux 1964, 1968; Stini 1969, 1975; Tobias 1970, 1972; Gray and Wolfe 1980) and those archaeologically derived (Finkel 1982b; Hall 1978; Hamilton 1982; Key 1980, Van Gerven 1971, 1972; Van Gerven and Oakland 1974; Willey 1982).

The majority of these studies attribute changes in the degree of sexual dimorphism to environmental factors such as malnutrition and disease. The premise states that under normal conditions both sexes will attain their genetic potential for size (most sexual dimorphism studies focus on stature in living samples or femur length in skeletal samples) with males being larger. Under adverse conditions the males will suffer more than the females since larger body sizes tend to require more energy to maintain them, and females appear to be able to better withstand hardships, perhaps due to their higher degree of canalization (Bielicki and Charzewski 1977) than males. The result is a net reduction in male stature while females remain relatively unchanged.

The work of Eveleth (1975) and Stini (1975) provides an alternative hypothesis. They claim that the evidence for environmental stress as a causative factor is weak. They prefer a genetic explanation. Eveleth supports this argument with an analysis of samples drawn from three major ethnic groups (Caucasoid, Negroid, and Amerindians). She found that of the three, Amerindians had the largest degree of sexual dimorphism. Eveleth argues that if environmental stress is the root cause of fluctuations in sexual dimorphism then the much more stressed Amerindians should have a lower sexual dimorphism value than the better

nourished European caucasoids. Since the opposite is true she claims that genetic factors are responsible. Eveleth (1975:38) concludes: ". . . it would appear that the use of sex dimorphism as an indicator of environmental conditions in a population could lead to many errors." She admits that there might be some value in comparing dimorphism in a single population through time as an indicator of environmental stress but, concludes that this will require further analysis.

A compromise between the two opposing positions views sexual dimorphism as the result of the complex interaction of genetic and environmental factors (Gray and Wolfe 1980; Willey 1980). Gray and Wolfe (1980) tested hypotheses regarding the relationship between environmental and genetic factors and sexual dimorphism. Their results were not conclusively in favor of either viewpoint. They found, on the one hand, that ". . . societies with poor protein availability are characterized by low mean male height and low degrees of sexual dimorphism in stature" thus, supporting the environmental stance. On the other hand, they also found that the greatest and the least degree of sexual dimorphism in height is found in those societies with high protein availability thus, supporting the genetic stance. As a result, they conclude that sexual dimorphism is most likely influenced by several factors, both environmental and genetic.

Finally, there is the recent sociobiological hypothesis. This camp claims that patterns of sexual dimorphism are influenced by factors of human behavior such as mating practices and work roles (Hall 1982). However, Gray and Wolfe's (1980) analysis of sexual dimorphism in human societies failed to establish a relationship between polygynous marriage and sexual dimorphism.

It would appear then that the debate over the causes of changing patterns of sexual dimorphism is far from over. It is the purpose of the present discussion to determine what, if any, contribution the Arikara analysis can make to the debate.

Eveleth (1975) suggests that an analysis of sexual dimorphism in a single population through time may have some value in determining the role of environmental stresses. The nature of the Arikara sample lends itself to such hypothesis testing. The sample approximates a single genetic lineage that spans a 250 year interval and is spatially circumscribed. In addition, the Arikara are known to have undergone severe environmental stress during the period sampled. The sample is large and is sexed as accurately as can be hoped for when working with archaeological material.

Patterns of changing Arikara sexual dimorphism were tested for with the interaction effect of the MANOVAs. The

null hypothesis in all sex tests is that there are no group differences in the magnitude of sex differences. In other words, an individuals group affiliation has no relationship to his group's level of sexual dimorphism. The components produced by the principal component analyses served as the dependent variables therefore, not only were components of limb length tested but, components of robusticity, shaft dimensions, and shape relationships were tested as well. In all six analyses the overall tests of significance for the interaction effect were nonsignificant (see Tables 4, 7, 9, 12, 14, and 16, pp. 56, 62, 63, 68, 70, and 72, respectively) thus, the null hypotheses could not be rejected.

These results would tend to support Eveleth (1975) and Stini's (1975) contention of a genetic basis for sexual dimorphism. If environmental stresses were responsible there should be a decrease in the level of Arikara sexual dimorphism. During the period sampled by the present analysis the Arikara suffered increasing environmental stress in the forms of warfare, epidemic diseases, and starvation (Bass et al. 1971; Lehmer 1971; Lehmer and Jones 1968; Owsley et al. 1977; Smith 1972).

However, it is possible that the results may only appear to support a genetic basis for dimorphism. Hamilton (1982:131) states:

> While it may be prudent to test for statistically significant differences in the magnitude of

> dimorphism between populations, the actual differences are often very small and the quality of the analysis may be limited further by small sample sizes. In such cases the consistency of change in dimorphism between the populations compared for a number of different measurements may be all that supports the contention that the demonstrated differences are real.

This logic has some flaws, such as a misunderstanding of the nature of analysis of variance (the method Hamilton uses) and the logic of performing a statistical analysis and then ignoring the results. Nevertheless, it may be fruitful to examine the trends in the values of some of the measurements.

Sexual dimorphism values for maximum femur lengths were calculated for groups with pooled sample sizes of 15 or more with the following formula:

$$\text{Sexual Dimorphism} = \frac{\text{Male X} - \text{Female X}}{\frac{\text{Male X} + \text{Female X}}{2}} \times 100 \qquad (6\text{-}1)$$

The values are presented in chronological order in Table 18. Also included in Table 18 are the sexual dimorphism values calculated by Willey (1982:140), using the same formula, for five of the same groups included in the present analysis.

Willey's values show a consistent decrease in sexual dimorphism through time, a pattern consistent with an environmental interpretation. However, the present analysis includes the three components from the Sully (39SL4) site. Their inclusion creates an apparently randomly fluctuating

Table 18. Median Dates, Femur Sample Sizes, Means, Standard Deviations, and Sexual Dimorphism Values for Groups, by Investigator.

Group Investigator	Median Date	Males			Females			Dimorphism Value
		N	Mean	S.D.	N	Mean	S.D.	
Rygh	1625							
Willey		8	449.9	13.7	4	408.8	24.4	9.57
Zobeck		10	456.2	15.8	9	414.6	18.8	9.6
Mobridge 1	1625							
Willey		14	455.1	20.4	16	414.4	17.9	9.36
Zobeck		21	451.8	18.1	19	410.4	18.7	9.6
Sully D	1662							
Willey								
Zobeck		13	452.5	20.6	8	420.6	23.7	7.3
Sully A	1678							
Willey								
Zobeck		11	447.2	11.9	8	413.1	17.6	7.9
Mobridge 2	1687							
Willey		10	448.6	13.7	7	412.6	8.2	8.36
Zobeck		41	450.2	16.3	36	411.4	13.7	9.0
Sully E	1687							
Willey								
Zobeck		15	449.9	15.3	5	413.8	11.7	8.4
Larson	1706							
Willey		59	445.9	16.8	66	417.4	20.4	6.60
Zobeck		68	446.4	18.2	66	415.9	18.8	7.1
Leavenworth	1817							
Willey		29	450.5	22.1	25	423.1	17.4	6.27
Zobeck		27	454.6	19.6	16	419.8	18.5	8.0

pattern. Excluding them and comparing the values for just those groups common to both analyses does not resolve the problem. While the present analysis' values for Rygh, Mobridge 1, Mobridge 2, and Larson do show a consistent decrease in dimorphism the value for Leavenworth reverses the trend. The discrepancy between the results is probably the result of two factors: (1) the differences in sample sizes and (2) interobserver error, Willey's values were calculated from data collected by several observers.

In the present analysis, Leavenworth's increased value after a steady trend of decreasing values is surprising within an environmental context considering that this period in Arikara history is marked by severe stress caused by overcrowding and the depletion of natural resources (Bass et al. 1971; Lehmer 1971; Smith 1972).

An examination of the femur length means reveals an interesting feature concerning the nature of Leavenworth sexual dimorphism. Both males and females gain in overall femur length with males gaining the most, which results in the overall gain in group sexual dimorphism. This is the classic pattern, offered by the supporters of the environmental approach, of a less stressed population; it suggests that the Leavenworth Arikara were experiencing less stress than their ancestors. In relative terms this may be true. The Arikara living at Leavenworth were the survivors or

descendants of survivors of several devastating epidemics. They would therefore tend to be well adapted to an environment that while not lacking in stress, may have been relatively less stressed than earlier ones. Perhaps Owsley's current research into skeletal indicators of stress among the Arikara will shed some light on the problem.

On the basis of these conflicting results it would be premature and unwarranted to conclude that group differences in sexual dimorphism are the result of solely genetic, environmental or biosociological factors. On the one hand, the MANOVA results indicate that there are no group differences in the magnitude of sex differences. In light of the increasing environmental stresses acting upon the Arikara through time these results would tend to support a genetic hypothesis. On the other hand, the sexual dimorphism values calculated on the mean femur lengths suggest there may be some environmental influences at work.

The picture is further clouded by possible methodological problems that are encountered when working with skeletal samples (Hamilton 1982). One such problem that may effect the present results is age related changes in bone morphology which may mask true sexual dimorphism differences. For this reason Hamilton (1982) cautions against comparing samples with differing age structures. For the Arikara there may be significant differences in the

demographic profiles of the various sites, especially with regard to Sully where the impression is that individuals regularly survived into later age categories (Owsley, personal communication). Results of the Arikara demographic study, currently underway, may enable future analyses to control for age related effects.

Summary

The present analysis was instigated in order to identify patterns of intra- and interpopulation variation. While not conclusive, the results do indicate that the patterns of intrapopulation variation identified for the Arikara samples may apply to other populations as well. Furthermore, the results do not demonstrate that the Arikara samples vary along these lines of variation to any great extent. This is most likely the result of a high degree of homogeneity among broad ethnic categories. Finally, patterns of changing sexual dimorphism among the Arikara tend to support a strong genetic component to this variation, though the results are not conclusive.

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APPENDICES

APPENDIX A

MEASUREMENT DEFINITIONS

The following 57 measurements were obtained from the literature or were devised especially for this study. Each measurement has been assigned a three letter code following the example of Howells (1973). Following the name of each variable is the three letter code, the source and the measuring instrument. The following is a key explaining the source and measuring instrument codes:

Source	Instrument
1. Bass (1971)	A. Osteometric Board
2. Hrdlička (1939)	B. Sliding Calipers
3. Ingalls (1924)	C. Spreading Calipers
4. Martin and Saller (1957)	D. Steel Tape
5. McHenry and Corrucini (1978)	E. Protractor
6. Montagu (1960)	
7. Trotter and Gleser (1952)	
8. Wilder (1920)	
9. Present study	

1. Humerus-maximum length: (HML, 1, A) Place the head against the fixed vertical of the board and adjust the movable upright to the distal end. Raise the bone slightly and move it up and down as well as from side to side until the maximum length is obtained.

2. Humerus-breadth of the upper epiphysis: (BUE, 5, A) Widest distance across the upper epiphysis; being sure to include the greater tubercle.

3. Radius-maximum length: (RML, 1, A) Maximum length from head to tip of the styloid process. Head is placed against the fixed vertical section of the osteometric board and the movable portion is adjusted to the distal end. Bone is raised slightly and moved up and down and from side to side until maximum length is obtained.

4. Ulna-maximum length: (UML, 1, A) Maximum length from the top of the olecranon process to the tip of the styloid process.

5. Femur-maximum length: (FML, 1, A) Place the distal condyles against the fixed vertical of the board and the movable upright to the head. Raise the bone slightly and move up and down as well as from side to side until maximum length is obtained.

6. Femur-oblique length: (FOL, 4, A) Place both condyles in contact with the vertical foot board, reading of plane parallel to foot board and tangent to head.

7. Femur-trochanteric length: (FTL, 4, A) Greatest distance between top of greater trochanter and external condyle.

8. Tibia-maximum length: (TML, 8, A) End of malleolus against vertical wall of the osteometric board, bone resting on its dorsal surface with its long axis parallel with the long axis of the board, block applied to the most prominent part of the lateral half of the lateral condyle.

9. Tibia-maximum breadth of the proximal epiphysis: (BPE, 5, A) Maximum distance between the medial and lateral condyles.

10. Tibia-maximum breadth of the distal epiphysis: (BDE, 5, A) Maximum distance between the fibular articular surface and the medial surface of the medial malleolus.

11. Fibula-maximum length: (BML, 1, A) Maximum distance between the proximal and distal extremities.

12. Clavicle-maximum length: (CML, 1, A) Maximum distance between the lateral and medial extremities. The bone is moved from side to side and up and down until the maximum length is obtained.

13. Humerus-maximum diameter of midshaft: (MDS, 1, B) Taken at exactly mid-length. Maximum diameter in an anterior-medial direction.

14. Humerus-minimum diameter of the midshaft: (MDM, 1, B) Diameter taken at right angle to number 13 above.

15. Humerus-maximum diameter of head: (MDH, 1, B) Taken from a point on the edge of the articular surface of the bone across to the opposite side. The bone is rotated until the maximum distance is obtained.

16. Humerus-epicondylar breadth: (EBR, 5, B) Maximum distance across the epicondyles on the distal end.

17. Radius-maximum diameter of the head: (RDH, 7, B) Taken from a point on the edge of the articular surface of the bone across to the opposite side. The bone is rotated until the maximum distance is obtained.

18. Ulna-maximum breadth of the olecranon process: (BOP, 5, B) Measured from the medial and lateral margins of the olecranon process' articular surface at its greatest breadth.

19. Ulna-minimum breadth of the olecranon process: (MBO, 9, B) Measured from the medial and lateral margins of the olecranon process' articular surface where the constriction on the medial margin becomes apparent.

20. Ulna-maximum width of the olecranon process: (WOP, 5, B) Measured in an antero-posterior direction from the anterior most portion of the olecranon process to the posterior most portion.

21. Ulna-olecranon process to radial notch length: (ORL, 9, B) From the most anteriorly projection point on the olecranon process to the inferior most margin of the radial notch.

22. Ulna-olecranon process to coronoid process length: (OCL, 5, B) From the most anteriorly projecting point on the olecranon process to the radial most margin of the coronoid process.

23. Femur-subtrochanteric anterior-posterior diameter: (APD, 1, B) Taken on the shaft just below the lesser trochanter, with the gluteal tuberosity avoided.

24. Femur-subtrochanteric medial-lateral diameter: (MLD, 1, B) Taken at same level as number 23 above and perpendicular to it.

25. Femur-anterior-posterior diameter of the midshaft: (APS, 1, B) Locate midshaft point on osteometric board and mark bone with pencil. Measure maximum anterior-posterior diameter.

26. Femur-medio-lateral diameter of the midshaft: (MLS, 1, B) Taken at right angle to number 25 above.

27. Femur-vertical head diameter: (VHD, 4, B) The greatest vertical diameter in the vertical plane passing through the axis of the neck.

28. Femur-horizontal diameter of the head: (HHD, 4, B) The maximum diameter at right angle to number 27 above.

29. Femur-anterior-posterior diameter of the lateral condyle: (APL, 6, B) The projected distance between the most posterior point on the lateral condyle and lip of the patellar surface taken perpendicular to the axis of the shaft.

30. Femur-anterior-posterior diameter of the medial condyle: (APM, 6, B) The projected distance between the most posterior point on the medial condyle and the lip of the patellar surface taken perpendicular to the axis of the shaft.

31. Tibia-anterior-posterior diameter at the nutrient foramen: (APN, 1, B) Maximum anterior-posterior diameter of shaft at the nutrient foramen.

32. Tibia-medio-lateral diameter at the nutrient foramen: (MLM, 1, B) Maximum transverse diameter at right angle to number 31 above.

33. Tibia-position of the nutrient foramen: (CFL, 9, B) Measured from the top of the lateral intercondylid eminence to the most distal point of the foramen.

34. Scapula-maximum length: (SML, 1, B) The maximum straight line distance from the superior to the inferior border.

35. Scapula-maximum breadth: (SMB, 1, B) From the middle of the dorsal border of the glenoid fossa to the spinal axis on the vertebral border.

36. Scapula-length of spine: (SLS, 1, B) From the end of the spinous axis on the vertebral border to the most lateral point of the acromion process.

37. Scapula-length of supra-spionus line: (SSL, 1, B) From the end of the spinous axis on the vertebral border to the top of the anterior angle.

38. Scapula-length of infra-spinous line: (ISL, 1, B) From the end of the spinous axis on the vertebral border to the tip of the inferior angle.

39. Scapula-glenoid cavity breadth: (GCB, 5, B) Taken at a point just below the constriction of the ventral border. Measured across the breadth of the glenoid cavity from the ventral to the dorsal margin.

40. Scapula-glenoid cavity height: (GCH, 5, B) Taken from the superior to the inferior margin of the glenoid cavity, being sure that the measurement is taken perpendicular to number 39 above.

41. Scapula-mid-glenoid to inferior angle length: (GIL, 3, C) Taken from the middle of the glenoid cavity to the inferior angle.

42. Ulna-physiological length: (UPL, 1, C) The two measuring points being the deepest point in the longitudinal ridge running across the floor of the semilunar notch and the deepest point of the distal surface of the head, not taking the groove between it and the styloid process.

43. Femur-epicondylar breadth: (FEB, 4, C) Measured over the most outstanding points of the epicondyles, parallel to the infracondylar plane.

44. Femur-bicondylar breadth: (BCB, 2, C) Greatest breadth across the condyles (transverse condylar breadth) taken at a point in the middle of each condyle (posteriorly).

45. Humerus-least circumference of the shaft: (LCS, 1, D) Taken at about the second third of the shaft, distal to the deltoid tuberosity.

46. Radius-maximum circumference of the shaft: (MCS, 9, D) Taken at a point just superior to the radial tuberosity.

47. Ulna-least circumference of the shaft: (ULC, 1, D) Located a little above the distal epiphysis, where the shaft, through the reduction of the muscular ridges and crests, becomes nearly cylindrical.

48. Femur-minimum vertical diameter of the neck: (VDN, 9, B) The minimum vertical diameter of the neck (taken in conjunction with femoral neck angle--see below).

49. Femur-capito-collar length: (CCL, 9, B) The length of the head and neck from the center of the head, as

projected onto the articular surface, to the coaxial point (measured directly from the drawing produced by the measurement of the femoral neck angle--see below).

50. Femur-neck angle: (FNA, 9, E) (See Figure A-1) With the anterior aspect down, on an underlying sheet of paper, place the distal condyles against the fixed vertical of the board. Just below midshaft measure the medial-lateral diameter of the shaft, being sure to mark the endpoints of the diameter on the paper with the tips of the sliding calipers. Repeat this procedure just above midshaft. Next, without moving the bone, measure the minimum vertical diameter of the neck, again marking the endpoints on the paper. Then, place a straight edge flush with the tip of the articular surface of the head and approximately perpendicular to the long axis of the neck. Remove the bone while keeping the straight edge in place. Draw a line along the straight edge. Mark all points made with the calipers with a pencil. For each set of points determine the midpoint of the diameter (points A, B, and C). For the two sets of points along the shaft draw a straight line through the midpoints (A and B), extending the length of the paper. This line represents the long axis of the shaft. For the neck diameter, place a protractor along the diameter and centered at point C. Draw a line that is perpendicular to the diameter and extends through the line of the long axis of the shaft and through the articular surface line. This line represents the long axis of the neck. Where it intersects the long axis of the shaft is the coaxial point (D), where it intersects the articular surface line is the center of the head as projected to the articular surface (point E). The angle can then be measured at point D with a protractor.

51. Femur-femoral condyle angle: (FCA, 9, E) This angle can be easily obtained with the schematic diagram produced in measurement 50 above (see Figure A-1). The angle is measured at point F, where the long axis of the shaft intersects the line formed by the edge of the paper that is flush with the fixed vertical end of the board. This edge represents the transverse plane of the condyles.

52. Scapula-lateral border angle: (LSA, 9) Of the inferior scapular body, the angle at the dorsal margin of the glenoid cavity, whose sides are maximum breadth

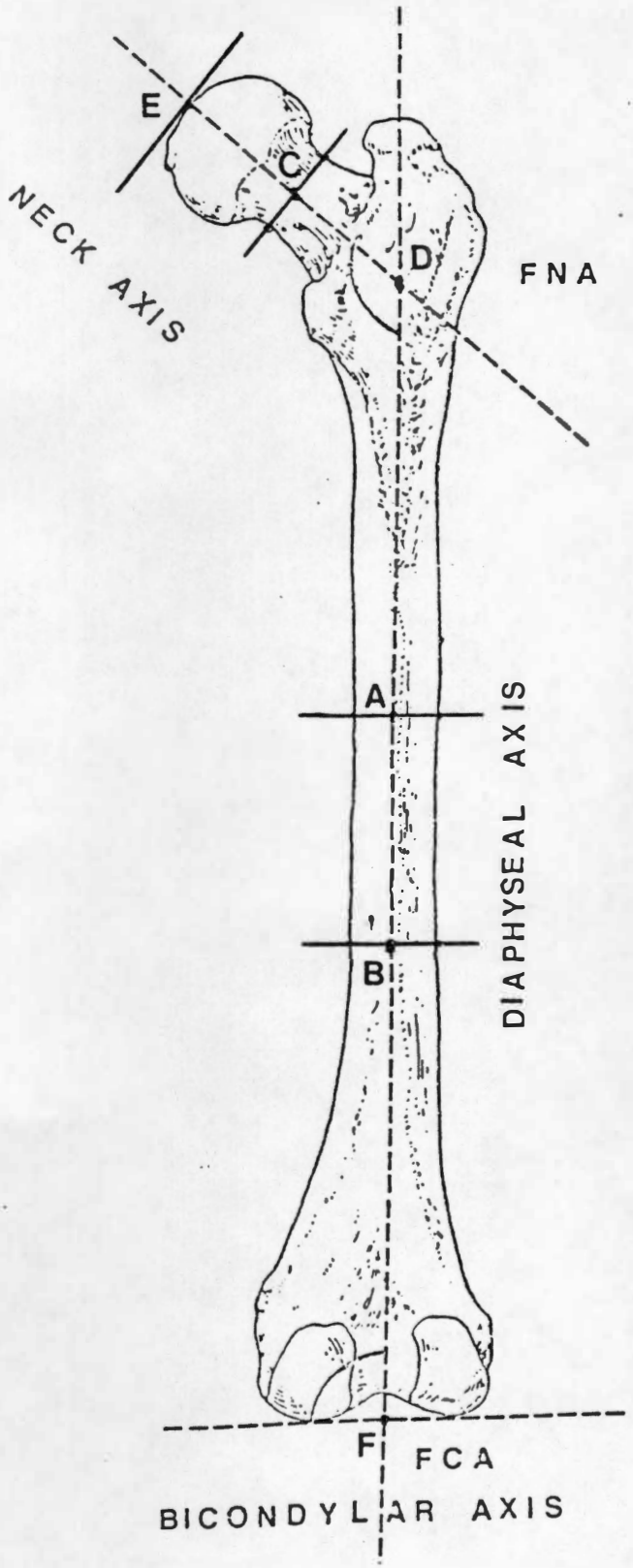


Figure A-1. Technique for Measuring Angles of the Femur.

and mid-glenoid to inferior angle length. Computed from the three sides of the triangle, maximum breadth, mid-glenoid to inferior angle length, and infraspinous line length.

53. Scapula-vertebral border angle: (VSA, 9) Of the inferior scapular body, the angle at the point of the spinous axis on the vertebral border, whose sides are maximum breadth and infraspinous line length. Computed from the three sides of the triangle, maximum breadth, infraspinous line length and mid-glenoid to inferior angle length.

54. Scapula-inferior angle: (ISA, 9) Of the inferior scapular body, the angle at the inferior border, whose sides are mid-glenoid to inferior angle and infraspinous line length. Computed from maximum breadth, mid-glenoid to inferior angle length and infraspinous line length.

55. Scapula-superior angle: (SSA, 9) Of the medial scapula body, the angle at the superior border, whose sides are supraspinous line length and maximum length. Computed from maximum length, supraspinous line length and infraspinous line length.

56. Scapula-caudal angle: (CSA, 9) Of the medial scapular body, the angle at the inferior border, whose sides are maximum length and infraspinous line length. Computed from maximum length, supraspinous line length and infraspinous line length.

57. Scapula-medial angle: (MSA, 9) Of the medial scapular body, the angle at the point of the spinous axis on the vertebral border, whose sides are supraspinous line length and infraspinous line length. Computed from maximum length, supraspinous line length and infraspinous line length.

APPENDIX B

DESCRIPTIVE STATISTICS

Table B-1. Sample Sizes for Each Bone by Group, by Sex.

Group	Sex	Scapula	Clavicle	Humerus	Ulna	Radius	Femur	Tibia	Fibula
Stony Point	1	3	3	3	3	3	3	3	3
Stony Point	2	4	4	5	5	5	5	4	3
Mobridge F1	1	16	16	21	19	19	21	23	21
Mobridge F1	2	16	17	22	17	20	19	19	21
Mobridge F2	1	33	43	47	46	45	41	50	46
Mobridge F2	2	19	27	34	26	30	36	33	32
Larson	1	55	79	76	73	76	68	76	78
Larson	2	43	74	78	71	78	66	70	75
Four Bear	1	1	1	3	1	0	0	2	1
Four Bear	2	1	4	5	2	2	3	5	5
Sully A	1	10	13	13	9	13	11	17	18
Sully A	2	5	9	10	7	9	8	8	8
Sully D	1	14	18	19	16	16	13	14	17
Sully D	2	9	12	11	7	9	8	8	13
Sully E	1	8	14	14	13	13	15	13	18
Sully E	2	2	4	4	9	9	5	8	9
Leavitt	1	3	5	5	4	5	4	5	4
Leavitt	2	0	1	1	1	0	2	2	2
Oahe Village	1	2	2	5	4	5	6	6	6
Oahe Village	2	0	0	1	1	1	0	1	1
Swan Creek	1	3	4	4	7	6	3	4	4
Swan Creek	2	2	3	3	3	3	2	2	3
Rygh	1	7	8	9	9	10	10	11	9
Rygh	2	6	8	11	10	8	9	8	10
Leavenworth	1	19	28	28	22	24	27	26	28
Leavenworth	2	8	21	22	14	18	16	17	17

1 = Males; 2 = Females.

Table B-2. Means by Group, by Sex, Section 1.

Group	Sex	HML	BUE	RML	UML	FML	FOL	FTL	TML	BPF	BDE	BML	CML	MDS	MDM	MDH	EBR	RDH	BOP	MBO
Stony Point	1	325.0	50.0	256.3	277.0	462.0	457.7	440.7	386.3	79.3	53.3	377.7	155.3	21.0	15.7	46.3	63.3	22.7	27.3	14.0
Stony Point	2	299.2	44.4	230.2	250.4	425.2	418.8	402.8	347.5	69.3	48.3	336.0	141.5	20.4	14.8	40.8	56.2	20.8	24.2	15.4
Mobridge F1	1	320.4	49.2	254.2	271.8	451.8	448.3	429.4	374.7	77.0	52.6	366.5	152.6	22.1	16.0	46.9	60.8	22.7	26.5	16.7
Mobridge F1	2	295.9	44.0	227.4	246.3	410.4	405.1	392.3	341.5	70.4	48.1	331.4	140.9	20.8	14.9	40.9	55.6	20.4	24.4	16.2
Mobridge F2	1	323.6	49.8	255.2	275.0	450.2	447.3	428.5	383.0	78.4	53.5	372.0	159.3	21.3	16.0	46.5	61.3	22.6	26.2	15.5
Mobridge F2	2	300.6	44.4	230.7	251.7	411.4	405.9	392.5	347.1	69.3	47.0	339.3	139.3	20.2	14.6	21.0	55.2	20.2	23.5	14.7
Larson	1	319.5	48.6	253.7	274.5	446.4	442.9	425.9	378.2	78.5	53.2	369.8	138.2	21.2	15.6	46.3	61.0	22.7	26.5	16.3
Larson	2	298.3	43.1	233.0	253.0	415.9	411.1	397.7	350.6	69.5	47.3	342.2	141.6	20.1	14.5	40.8	55.3	20.4	23.9	15.4
Four Bear	1	336.0	49.3	-----	277.0	-----	-----	-----	399.0	78.0	54.0	393.0	163.0	22.0	15.0	46.7	59.0	----	26.0	14.0
Four Bear	2	290.6	42.4	225.5	245.0	407.7	401.3	390.3	342.2	67.6	45.6	331.0	136.0	18.8	15.2	41.6	53.2	20.5	22.0	15.0
Sully A	1	316.1	49.5	254.2	272.1	447.2	444.0	428.7	379.4	78.4	52.8	368.3	157.9	21.2	15.6	46.3	60.5	22.8	27.2	15.7
Sully A	2	293.8	44.1	232.2	252.3	413.1	408.3	397.4	348.1	69.3	46.8	344.6	140.4	19.6	14.6	40.4	56.4	20.6	24.0	15.9
Sully D	1	319.2	49.3	252.9	275.2	452.5	448.7	432.4	382.2	78.9	53.2	369.1	148.3	21.5	15.4	46.4	61.0	22.7	26.6	14.8
Sully D	2	294.0	43.4	234.6	250.0	420.6	415.3	404.9	357.9	71.4	49.5	340.8	142.3	19.8	14.8	41.1	55.5	21.0	23.7	15.6
Sully E	1	316.1	49.0	251.1	273.2	449.9	445.4	427.7	380.9	79.8	53.7	370.7	156.1	21.4	15.6	46.6	61.1	22.2	26.4	16.5
Sully E	2	292.8	44.0	226.4	248.9	413.8	408.0	396.8	345.0	69.3	47.4	340.9	140.5	19.8	14.5	42.0	54.5	20.7	23.8	15.9
Leavitt	1	320.6	49.2	257.4	273.0	459.0	454.5	436.5	386.8	79.0	54.4	380.5	157.2	21.2	16.0	46.2	61.0	23.0	26.3	15.0
Leavitt	2	298.0	44.0	-----	245.0	426.5	420.5	403.5	345.5	70.5	49.0	342.0	141.0	19.0	14.0	41.0	53.0	----	23.0	15.0
Oahe Village	1	322.8	48.6	254.2	272.8	441.2	438.5	421.5	378.0	76.5	52.2	368.0	158.0	21.4	16.2	45.4	59.8	22.4	24.8	15.0
Oahe Village	2	300.0	42.0	235.0	257.0	-----	-----	-----	354.0	70.0	47.0	345.0	-----	22.0	14.0	39.0	55.0	21.0	25.0	16.0
Swan Creek	1	321.8	41.3	252.2	270.4	456.7	459.9	437.7	392.0	79.5	54.8	383.0	161.5	21.8	16.3	46.0	61.0	22.5	26.1	15.3
Swan Creek	2	297.3	43.0	226.3	247.0	410.0	404.0	389.5	334.0	67.5	46.0	341.3	143.7	19.3	13.3	39.7	52.7	19.7	21.3	14.0
Rygh	1	319.9	47.7	254.1	273.0	456.2	448.7	430.8	380.6	77.2	52.8	372.0	153.5	21.0	15.1	46.4	59.4	22.4	26.2	14.8
Rygh	2	292.2	43.5	229.5	251.6	414.7	410.9	396.3	338.5	69.8	47.5	331.8	140.8	20.8	14.3	40.8	54.8	20.6	24.5	15.6
Leavenworth	1	322.6	48.6	255.4	273.5	454.6	451.6	435.3	388.0	78.8	52.7	378.4	158.4	21.8	16.1	46.4	60.5	22.8	26.0	15.4
Leavenworth	2	306.5	44.9	232.8	254.9	419.8	414.7	399.4	349.9	68.1	45.3	345.6	141.2	21.0	14.7	42.1	55.0	20.7	24.1	15.2

Table B-3. Means by Group, by Sex, Section 2.

Group	Sex	WOP	ORL	OCL	APD	MLD	APS	MLS	VHD	HHD	APL	APM	APN	MLM	NFL	SML	SMB	SLS	SSL	ISL
Stony Point	1	26.3	35.7	26.3	24.7	35.0	30.0	27.3	49.3	49.0	67.0	64.0	34.7	26.0	123.7	166.7	99.3	132.0	51.3	130.0
Stony Point	2	23.2	32.4	23.2	22.2	32.4	25.8	25.0	43.0	42.6	61.4	60.0	29.8	21.8	116.3	145.8	95.5	127.0	44.5	114.0
Mobridge F1	1	25.7	34.5	24.2	25.1	34.4	29.9	26.3	46.5	46.6	66.3	65.6	36.8	24.4	119.4	158.5	104.9	136.1	50.6	120.8
Mobridge F1	2	23.6	32.5	22.3	22.8	31.2	26.3	24.5	43.1	42.4	60.8	58.6	32.0	22.7	110.1	143.8	96.5	126.1	45.3	111.8
Mobridge F2	1	25.4	34.1	24.6	25.0	34.1	30.3	26.9	46.6	46.2	66.6	65.9	38.5	23.1	120.4	158.6	105.4	139.0	52.8	118.6
Mobridge F2	2	23.4	31.8	22.0	21.9	31.2	25.6	24.3	42.0	41.6	60.8	59.5	31.2	21.8	109.4	141.7	97.5	126.1	47.9	106.8
Larson	1	25.1	34.8	24.6	24.9	33.8	29.6	26.8	47.0	46.6	66.9	66.2	37.6	24.0	119.2	158.1	103.9	137.7	52.4	118.2
Larson	2	23.8	32.1	22.8	22.1	30.8	25.5	24.4	42.0	41.5	61.0	59.3	31.4	21.6	110.9	141.7	95.2	124.9	46.6	107.3
Four Bear	1	25.0	36.0	----	----	----	----	----	----	----	----	----	38.0	22.0	130.0	162.0	103.0	137.0	55.0	120.0
Four Bear	2	21.5	31.5	22.0	22.3	30.7	26.0	24.0	42.3	41.7	60.7	60.3	30.4	22.4	104.4	139.0	98.0	126.0	47.0	105.0
Sully A	1	25.9	37.8	24.0	25.3	35.6	30.6	27.2	47.5	47.3	67.2	66.5	37.8	23.1	119.2	160.2	102.0	137.7	51.5	122.6
Sully A	2	23.9	31.4	22.4	21.5	31.0	25.4	24.1	42.4	42.1	60.8	58.8	30.3	22.3	119.5	145.6	96.6	125.6	49.0	109.0
Sully D	1	25.8	35.6	26.1	24.3	35.3	29.1	26.6	46.3	46.2	65.5	65.6	37.4	22.1	119.4	158.4	105.6	140.6	53.0	119.4
Sully D	2	23.6	34.4	24.4	23.9	32.4	27.4	24.1	43.4	42.9	62.3	61.4	32.8	22.1	116.9	140.1	96.7	126.0	44.7	107.2
Sully E	1	26.2	36.2	24.8	25.3	36.7	29.9	27.1	47.4	47.1	67.4	65.7	37.6	23.7	122.0	157.3	102.8	135.8	49.9	120.6
Sully E	2	23.9	33.3	22.2	21.8	31.2	24.8	23.8	44.8	43.0	51.8	59.4	30.4	22.3	107.6	147.5	99.0	129.5	46.0	114.5
Leavitt	1	25.3	33.8	24.3	26.0	33.5	31.5	26.8	48.3	47.3	68.8	66.5	39.6	24.4	121.4	163.0	102.7	138.3	58.3	124.7
Leavitt	2	24.0	29.0	21.0	22.0	30.5	27.0	23.5	45.0	44.5	61.5	59.5	32.0	23.5	100.5	-----	-----	-----	----	-----
Oahe Village	1	25.3	34.3	24.3	24.3	34.0	28.0	26.3	26.5	45.8	66.2	63.8	36.7	22.0	123.3	150.5	102.0	136.5	52.5	109.9
Oahe Village	2	25.0	34.0	23.0	----	----	----	----	----	----	----	----	30.0	19.0	112.0	-----	-----	-----	----	-----
Swan Creek	1	25.9	33.1	24.6	24.3	35.0	31.0	27.3	48.3	47.7	68.3	65.7	39.5	24.3	124.0	169.7	105.7	140.3	53.3	131.0
Swan Creek	2	23.0	30.7	21.0	20.5	30.5	24.5	23.0	41.5	41.5	58.0	57.5	28.0	21.5	106.5	132.5	97.0	122.5	43.5	102.5
Rygh	1	24.3	33.4	23.7	23.9	34.4	29.6	26.0	46.8	46.4	66.2	65.7	36.8	23.9	119.5	154.3	104.1	136.7	51.7	117.1
Rygh	2	23.6	31.7	22.8	22.6	31.3	25.7	25.0	42.6	41.9	61.7	59.7	32.1	22.0	108.3	141.0	97.3	124.2	48.2	106.5
Leavenworth	1	25.3	34.8	24.5	26.2	34.4	31.0	27.4	47.3	47.1	67.1	65.7	37.9	23.9	122.8	160.0	103.2	138.1	50.0	121.5
Leavenworth	2	24.6	32.4	23.1	23.3	30.9	26.9	24.9	43.0	42.9	61.4	59.0	30.0	22.6	116.2	147.6	101.6	131.6	47.0	113.4

Table B-4. Means by Group, by Sex, Section 3.

Group	Sex	GCB	GCH	GIL	UPL	FEB	BCB	LCS	MCS	ULC	VDN	CCL	FNA	FCA	LSA	VSA	ISA	SSA	CSA	MSA
Stony Point	1	26.0	36.0	149.3	244.3	85.7	79.7	60.3	43.0	35.7	33.7	75.7	125.0	98.7	59.0	80.0	41.0	37.7	14.0	128.3
Stony Point	2	24.5	32.8	133.8	220.0	75.0	67.0	57.0	40.4	32.4	28.2	65.4	127.6	103.2	56.8	78.8	44.5	38.0	13.8	128.3
Mobridge F1	1	26.0	35.4	147.1	240.8	83.1	77.3	59.4	42.4	34.4	32.4	73.0	131.1	100.0	54.1	81.0	44.9	35.0	14.0	131.0
Mobridge F1	2	23.7	32.6	133.8	218.6	75.4	68.5	56.2	40.3	33.0	29.1	65.0	129.4	101.1	55.3	79.6	45.1	38.1	14.5	127.4
Mobridge F2	1	26.1	34.9	146.7	243.1	82.6	76.2	59.7	41.2	33.3	31.9	74.0	127.2	99.3	53.0	81.6	45.3	33.8	14.4	131.8
Mobridge F2	2	23.7	31.9	131.3	222.2	73.8	67.6	55.8	39.2	33.0	27.8	65.4	126.7	102.1	53.1	79.9	46.9	35.3	14.9	129.7
Larson	1	26.0	34.7	144.2	243.3	84.5	77.9	59.3	40.8	33.6	32.1	72.9	127.6	100.0	56.0	80.6	45.3	33.5	14.2	132.3
Larson	2	23.7	31.5	130.3	223.4	75.5	68.3	55.1	38.6	32.8	27.9	67.6	127.6	102.1	54.3	79.8	46.0	35.5	14.5	129.9
Four Bear	1	25.0	35.0	147.0	246.0	----	----	58.8	----	37.0	----	----	-----	-----	54.0	82.0	44.0	33.0	15.0	132.0
Four Bear	2	23.0	32.0	131.0	217.5	74.0	67.3	54.8	38.0	33.0	28.0	65.0	123.3	104.0	52.0	80.0	48.0	36.0	15.0	129.0
Sully A	1	28.3	35.6	143.2	240.2	83.8	76.4	59.2	42.8	34.1	32.5	65.0	122.8	101.2	56.0	78.7	44.3	36.0	14.4	129.6
Sully A	2	24.6	32.2	129.0	222.3	74.6	67.4	55.6	39.1	32.7	28.4	62.3	125.4	101.6	55.6	77.4	46.8	34.2	14.4	131.4
Sully D	1	26.6	35.8	146.7	243.8	82.8	76.9	58.8	41.1	33.6	32.6	71.3	126.0	99.4	53.5	81.2	45.4	35.2	14.9	130.0
Sully D	2	24.3	32.3	131.0	221.4	74.8	68.8	55.5	40.8	32.7	29.0	64.5	127.3	102.9	53.8	79.8	46.7	35.8	14.0	130.2
Sully E	1	25.4	36.5	145.8	242.2	84.7	76.2	59.2	41.6	33.7	32.5	73.3	127.8	101.0	54.8	81.0	44.0	36.0	14.0	130.0
Sully E	2	24.5	31.5	136.5	221.6	76.2	68.4	55.3	38.3	32.3	29.6	64.2	126.2	103.2	55.5	79.0	45.5	37.5	14.5	128.0
Leavitt	1	25.7	35.0	139.7	242.8	84.3	79.0	59.8	44.4	33.0	33.0	66.8	127.8	100.3	60.0	74.7	45.0	40.7	17.6	121.7
Leavitt	2	----	----	-----	217.0	75.5	70.0	53.0	----	32.0	31.0	60.0	131.5	102.0	----	----	----	----	----	-----
Oahe Village	1	24.5	35.0	145.5	242.3	81.2	75.0	59.2	40.0	32.8	31.3	72.0	125.2	99.8	48.5	87.0	44.5	31.0	14.5	134.5
Oahe Village	2	----	----	-----	225.0	----	----	58.0	38.0	32.0	-----	-----	-----	----	----	----	----	----	----	-----
Swan Creek	1	26.0	35.7	150.0	236.6	83.3	78.7	60.5	41.8	35.3	33.7	74.0	124.7	101.0	59.0	77.7	43.3	36.7	14.0	129.3
Swan Creek	2	22.5	29.0	126.5	219.0	73.0	67.5	52.3	39.3	31.7	26.5	56.5	132.0	101.5	52.5	78.5	49.0	39.0	15.5	125.5
Rygh	1	25.9	34.6	141.3	243.8	82.9	77.6	58.1	40.4	33.1	31.8	71.7	127.0	99.2	54.4	79.3	46.3	36.7	15.3	128.0
Rygh	2	24.0	31.3	129.2	222.7	74.2	67.2	55.7	39.6	34.2	28.2	67.1	126.3	101.2	54.2	78.5	47.7	36.8	15.7	127.5
Leavenworth	1	26.0	35.1	144.4	243.8	85.1	77.4	60.3	43.8	34.1	32.4	75.2	125.7	99.2	55.9	79.4	44.6	33.1	12.9	134.0
Leavenworth	2	24.3	33.1	136.8	225.6	75.2	67.5	57.3	39.7	33.4	28.6	66.6	128.0	102.1	54.8	78.5	46.6	36.4	14.3	129.4

Table B-5. Standard Deviations by Group, by Sex, Section 1.

Group	Sex	HML	BUE	RML	UML	FML	FOL	FTL	TML	BPE	BDE	BML	CML	MDS	MDM	MDH	EBR	RDH	BOP	MBO
Stony Point	1	30.51	2.00	22.03	22.27	37.04	34.70	25.42	33.08	1.53	2.08	32.72	11.02	1.00	2.08	2.08	2.52	1.15	0.57	2.64
Stony Point	2	8.76	0.55	9.09	9.18	10.08	9.04	6.98	5.74	1.50	2.36	2.64	3.87	1.34	1.30	1.30	1.48	0.45	0.84	3.29
Mobridge F1	1	14.33	1.76	12.85	12.53	18.15	18.78	18.86	19.78	3.23	3.07	20.75	8.72	1.70	0.97	2.22	3.32	1.25	1.65	2.87
Mobridge F1	2	13.23	2.44	12.42	12.99	18.70	18.61	16.36	16.32	3.73	2.99	14.64	8.23	1.59	1.11	1.83	2.77	0.99	1.42	2.29
Mobridge F2	1	11.99	2.11	8.76	9.53	16.33	16.33	15.23	13.64	2.25	2.28	14.27	7.73	1.78	1.55	2.16	2.58	1.39	1.57	2.37
Mobridge F2	2	12.26	2.13	9.32	9.35	13.74	13.67	13.27	14.59	3.76	2.97	14.27	7.83	1.36	0.99	2.11	2.61	1.21	1.24	1.51
Larson	1	13.51	2.31	12.18	12.70	18.17	17.72	17.20	20.72	3.46	2.99	18.76	8.75	1.43	1.33	2.50	3.12	1.11	1.46	2.05
Larson	2	11.99	1.86	10.58	11.08	18.81	18.42	18.08	17.63	3.72	2.66	17.68	7.15	1.32	1.38	2.13	3.27	1.10	1.62	2.04
Four Bear	1	13.89	2.52	-----	-----	-----	-----	-----	2.83	7.07	1.41	-----	-----	1.00	2.00	2.08	2.65	----	----	----
Four Bear	2	5.13	1.52	4.95	1.41	5.86	6.43	3.79	8.38	1.14	2.19	11.51	4.32	0.45	1.30	4.39	1.30	0.71	0.00	2.12
Sully A	1	8.26	2.47	6.30	6.17	11.95	11.57	9.72	13.08	3.92	3.61	13.42	6.56	1.48	1.12	2.75	2.88	1.07	1.56	1.93
Sully A	2	8.59	1.29	8.23	10.69	17.59	17.09	16.34	15.38	2.66	1.28	22.44	5.66	1.78	1.26	1.17	2.37	0.88	1.53	2.85
Sully D	1	12.99	2.67	7.85	8.01	20.56	21.68	22.52	17.49	3.52	3.58	16.92	7.82	2.14	1.22	2.48	3.82	1.45	1.86	2.04
Sully D	2	13.94	1.80	14.28	14.50	23.71	22.78	23.23	14.74	3.25	2.14	17.63	9.87	1.08	1.33	1.58	2.38	1.22	1.60	2.15
Sully E	1	10.35	2.18	7.94	9.47	15.31	15.13	13.36	15.33	2.89	1.97	13.76	6.59	1.45	1.02	2.53	1.77	0.90	1.71	2.40
Sully E	2	13.65	1.41	10.01	11.15	11.69	10.82	10.03	10.43	3.49	3.58	21.07	6.14	1.50	0.58	1.15	3.51	0.87	1.39	1.27
Leavitt	1	11.06	1.48	3.36	3.92	8.98	8.06	8.96	9.04	3.32	1.82	14.67	7.19	1.09	1.00	0.84	3.39	0.71	1.71	0.82
Leavitt	2	-----	----	----	----	3.54	4.95	2.12	6.36	0.71	1.41	7.07	----	----	----	----	----	----	----	----
Oahe Village	1	9.63	1.52	9.44	11.50	20.45	20.05	19.85	22.75	2.26	1.94	23.43	4.24	2.19	1.92	1.14	2.77	0.89	1.71	2.45
Oahe Village	2	-----	----	----	-----	-----	-----	-----	-----	----	----	-----	----	----	----	----	----	----	----	----
Swan Creek	1	21.44	14.55	16.50	16.15	14.74	23.64	22.01	24.04	1.73	2.87	19.90	9.11	0.96	0.50	4.00	3.74	1.05	1.46	1.80
Swan Creek	2	5.13	1.78	1.52	6.24	19.80	18.38	21.92	8.49	0.71	0.00	29.67	3.21	0.58	0.58	2.08	2.08	0.58	0.58	1.00
Rygh	1	11.37	1.94	6.57	7.23	15.79	13.93	14.95	14.40	4.56	2.52	21.38	6.85	1.22	0.93	1.74	3.36	0.84	1.09	1.20
Rygh	2	13.89	2.07	10.99	11.03	18.81	19.47	21.00	20.11	2.96	2.39	15.02	9.53	1.40	1.62	1.89	3.99	1.30	1.65	1.84
Leavenworth	1	16.15	1.99	10.83	11.91	19.64	19.95	19.50	20.65	3.51	2.29	20.79	8.90	1.27	1.09	2.03	2.44	1.19	1.72	2.15
Leavenworth	2	13.80	1.54	9.90	8.92	18.46	18.01	18.95	16.03	3.30	3.24	17.02	9.61	1.45	1.03	1.93	3.25	1.08	1.77	1.76

Table B-6. Standard Deviations by Group, by Sex, Section 2.

Group	Sex	WOP	ORL	OCL	APD	MLD	APS	MLS	VHD	HHD	AOK	APM	APN	MLM	NFL	SML	SMB	SLS	SSL	ISL
Stony Point	1	1.15	3.21	3.05	1.15	1.00	1.00	1.53	2.08	2.64	2.65	9.93	0.58	2.65	15.82	8.62	4.93	7.00	2.89	9.00
Stony Point	2	1.30	1.67	1.92	1.30	1.14	0.84	1.73	1.73	1.14	1.14	1.73	2.06	2.06	13.96	4.27	4.12	4.97	1.29	5.94
Mobridge F1	1	1.89	2.39	1.61	1.70	2.54	2.22	2.37	1.89	2.18	3.14	3.47	3.27	1.95	9.94	12.01	4.28	7.61	6.11	11.33
Mobridge F1	2	1.54	2.09	1.86	1.86	2.14	2.33	1.90	2.41	2.24	2.78	2.75	3.07	2.47	10.33	6.42	7.69	6.98	3.65	4.88
Mobridge F2	1	1.58	1.87	1.82	1.58	1.61	2.05	1.21	2.24	2.65	2.31	2.35	2.62	2.20	9.44	7.31	3.54	4.39	5.16	6.66
Mobridge F2	2	1.50	2.44	1.78	1.37	1.80	1.78	1.51	2.06	2.21	2.77	3.79	2.38	2.36	8.44	6.83	5.33	6.11	5.65	5.95
Larson	1	1.50	1.99	1.79	1.51	1.87	2.19	1.47	2.05	2.02	3.04	3.06	2.45	1.97	9.75	7.87	5.69	6.93	5.52	6.20
Larson	2	1.59	1.90	1.58	1.71	1.78	2.34	1.39	2.13	2.17	3.21	3.89	2.52	2.15	9.06	6.78	6.10	5.84	3.97	6.13
Four Bear	1	----	----	----	----	----	----	----	----	----	----	----	0.00	2.83	1.41	----	----	----	----	----
Four Bear	2	2.12	2.12	1.41	1.53	0.58	1.00	1.00	1.53	2.08	3.06	0.58	0.55	2.07	8.05	----	----	----	----	----
Sully A	1	1.90	1.39	1.66	1.78	1.63	1.86	1.17	1.51	1.49	2.75	2.34	2.99	2.11	8.52	5.51	5.27	4.24	4.88	6.64
Sully A	2	1.07	1.81	0.79	1.31	1.31	1.85	0.83	1.92	1.64	1.83	1.39	3.11	2.92	14.53	7.89	2.88	5.59	4.36	7,81
Sully D	1	1.60	2.25	1.59	2.09	4.29	2.63	2.57	3.54	3.48	3.79	4.01	3.18	2.28	11.32	10.24	6.10	7.75	6.53	9.14
Sully D	2	1.40	1.62	2.30	1.73	3.46	1.60	1.64	1.41	2.03	3.33	3.02	2.31	1.64	6.58	8.78	5.39	4.61	3.74	8.23
Sully E	1	1.01	1.17	1.52	1.91	2.94	2.09	1.46	2.32	2.36	3.44	3.11	3.55	1.70	12.56	3.85	3.28	3.41	4.61	5.32
Sully E	2	1.36	1.80	1.30	1.48	0.84	0.64	0.84	1.79	2.55	2.17	1.52	2.13	1.75	8.21	12.02	0.00	0.71	2.83	9.19
Leavitt	1	0.50	0.96	1.26	1.83	1.00	1.73	0.96	2.06	2.06	4.03	1.29	1.52	2.61	9.13	8.00	7.57	11.59	6.66	8.96
Leavitt	2	----	----	----	1.41	0.71	2.83	0.71	0.00	0.71	0.71	0.71	1.41	0.71	16.26	----	----	-----	----	----
Oahe Village	1	1.50	1.26	1.26	1.60	2.61	2.19	2.66	2.17	1.47	2.79	2.64	2.80	1.55	10.93	0.71	2.83	2.12	2.12	2.83
Oahe Village	2	----	----	----	----	----	----	----	----	----	----	----	----	----	-----	----	----	----	----	----
Swan Creek	1	1.57	1.06	0.98	0.58	1.00	3.00	0.58	3.06	2.52	4.73	3.79	1.73	0.96	16.43	7.02	3.51	4.93	1.53	7.94
Swan Creek	2	1.73	1.53	1.73	0.71	2.12	0.71	0.00	0.71	0.71	1.41	0.71	0.00	0.71	9.19	0.71	1.41	0.71	0.71	0.71
Rygh	1	1.80	1.74	1.00	1.71	2.12	2.46	2.05	1.75	1.78	1.99	2.98	1.72	2.74	8.88	6.97	4.60	4.46	3.50	9.86
Rygh	2	1.26	1.34	1.69	1.13	2.12	1.58	1.32	1.94	1.62	2.40	2.18	2.17	1.60	6.07	5.37	2.88	5.78	4.71	3.21
Leavenworth	1	1.52	1.82	2.13	1.75	2.21	2.37	1.67	2.09	2.24	2.72	3.50	2.68	1.87	6.65	6.52	3.95	4.67	3.73	7.24
Leavenworth	2	1.50	1.56	1.44	2.41	1.59	2.24	1.34	1.63	1.57	2.87	3.08	2.40	1.58	7.32	6.57	4.90	6.37	5.45	5.37

Table B-7. Standard Deviations by Group, by Sex, Section 3.

Group	Sex	GCB	GCH	GIL	UPL	FEB	BCB	LSC	MCS	ULC	VDN	CCL	FNA	FCA	LSA	VSA	ISA	SSA	CSA	MSA
Stony Point	1	1.00	1.73	14.64	21.01	1.15	2.52	2.52	3.00	0.58	2.31	5.03	7.82	1.15	1.73	4.00	2.65	1.15	1.00	1.53
Stony Point	2	0.58	0.50	3.95	8.98	1.00	3.24	3.00	3.78	2.79	1.64	5.64	3.44	2.17	2.22	0.96	2.38	3.46	0.96	3.86
Mobridge F1	1	1.75	1.50	8.02	12.72	3.37	3.54	3.22	3.19	2.71	2.34	7.28	5.17	2.04	4.43	3.18	2.25	5.93	2.34	7.27
Mobridge F1	2	1.89	1.59	6.59	11.26	2.73	2.74	4.28	3.70	3.06	2.17	7.64	6.92	3.25	3.16	3.93	3.07	4.22	1.51	5.28
Mobridge F2	1	1.88	1.61	5.75	9.09	2.55	3.25	3.87	3.13	2.59	2.01	6.05	4.48	2.82	2.96	3.41	2.10	4.43	2.29	6.32
Mobridge F2	2	1.42	1.52	5.13	9.36	3.16	2.92	2.97	3.28	2.62	1.80	5.81	6.43	2.03	4.03	3.96	1.96	5.29	2.80	7.83
Larson	1	1.67	1.83	6.89	12.16	3.76	3.56	3.11	2.71	2.35	2.10	5.89	5.24	2.16	3.39	3.37	2.52	3.80	2.03	5.31
Larson	2	1.60	1.49	7.86	10.28	3.93	4.00	3.72	2.97	2.41	2.01	5.62	5.50	2.18	3.59	3.60	2.13	4.56	1.92	6.09
Four Bear	1	----	----	----	----	----	----	2.08	----	----	----	----	----	----	----	----	----	----	----	----
Four Bear	2	----	----	----	2.12	2.65	1.53	2.68	2.83	0.00	1.00	2.65	3.06	1.00	----	----	----	----	----	----
Sully A	1	1.06	2.22	3.12	5.74	3.22	4.90	3.11	3.51	1.83	1.21	5.93	5.71	2.23	4.06	3.71	3.16	3.80	1.90	5.10
Sully A	2	0.55	1.30	5.15	10.26	2.26	2.00	3.13	3.26	2.63	1.92	8.29	6.17	3.11	4.45	3.29	1.79	6.50	2.97	9.10
Sully D	1	1.70	2.49	7.48	7.47	4.24	2.90	4.37	3.15	2.36	3.12	8.90	5.17	2.84	3.13	3.83	2.85	4.17	2.35	6.11
Sully D	2	1.22	1.41	7.94	13.69	4.09	3.81	2.58	3.23	1.89	1.51	8.43	5.50	2.64	2.49	1.79	2.35	4.18	1.50	5.21
Sully E	1	1.06	1.60	4.71	9.26	3.13	3.51	2.58	1.71	2.46	2.07	5.23	5.06	1.85	3.85	3.93	2.14	2.51	2.20	4.00
Sully E	2	0.71	0.71	7.78	10.09	1.30	2.30	4.72	1.80	2.12	2.07	4.44	3.96	1.30	2.12	1.41	3.54	0.71	0.71	1.41
Leavitt	1	0.58	1.73	2.31	4.11	3.40	4.08	2.86	7.67	2.45	0.82	8.85	4.19	2.63	7.81	3.21	4.36	3.79	2.52	5.03
Leavitt	2	----	----	----	----	2.12	1.41	----	----	----	2.83	5.66	0.71	0.00	----	----	----	----	----	----
Oahe Village	1	0.71	1.41	2.12	10.28	3.06	0.89	5.40	2.45	2.06	1.51	7.46	2.99	3.37	0.71	1.41	0.71	1.41	0.71	0.71
Oahe Village	2	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Swan Creek	1	1.00	1.53	6.08	16.10	3.06	4.04	1.73	1.17	1.25	3.21	4.00	6.43	1.73	3.00	3.06	0.58	4.51	1.73	6.11
Swan Creek	2	0.71	1.41	2.12	5.19	2.83	2.12	1.15	5.13	2.08	3.54	7.78	4.24	0.71	0.71	2.12	1.41	2.83	0.71	3.54
Rygh	1	1.35	1.81	6.52	7.53	3.35	2.76	1.83	2.32	1.17	1.93	6.93	7.53	2.35	4.08	2.14	2.29	4.82	1.98	5.80
Rygh	2	1.26	1.03	7.36	11.10	3.15	2.39	4.31	2.62	2.74	1.99	4.59	5.34	2.22	2.32	3.51	1.21	3.13	2.34	5.32
Leavenworth	1	2.24	1.88	6.47	11.32	3.88	4.27	2.84	2.78	2.19	2.08	5.83	5.15	1.96	3.89	3.67	2.24	4.36	1.96	6.00
Leavenworth	2	0.71	0.83	6.68	8.52	3.25	3.20	3.31	3.04	2.01	1.26	3.97	4.38	1.96	5.75	5.01	1.69	3.11	2.05	4.66

APPENDIX C

CORRELATION MATRICES

Table C-1. Scapula: Pooled Within-Groups Correlation Matrix.

Variable	SML	SMB	SLS	SSL	ISL	GCB	GCH	GIL	LSA	VSA	ISA	SSA	CSA	MSA
SML	1.00													
SMB	0.38	1.00												
SLS	0.42	0.81	1.00											
SSL	0.57	0.31	0.36	1.00										
ISL	0.85	0.22	0.21	0.21	1.00									
GCB	0.42	0.38	0.33	0.22	0.32	1.00								
GCH	0.42	0.23	0.33	0.20	0.36	0.51	1.00							
GIL	0.65	0.60	0.62	0.31	0.52	0.40	0.37	1.00						
LSA	0.40	-0.35	-0.34	-0.04	0.68	-0.01	0.09	-0.25	1.00					
VSA	-0.20	-0.04	0.12	0.01	-0.40	-0.02	0.01	0.44	-0.77	1.00				
ISA	-0.33	0.55	0.32	0.03	-0.44	0.01	-0.15	-0.30	-0.35	-0.32	1.00			
SSA	0.13	-0.08	-0.16	0.18	0.46	-0.04	-0.01	-0.03	0.55	-0.44	-0.18	1.00		
CSA	0.12	0.03	0.04	0.73	0.06	-0.03	-0.01	-0.04	0.10	-0.14	0.06	0.66	1.00	
MSA	-0.13	0.04	0.10	-0.39	-0.36	0.04	0.01	0.03	-0.44	0.37	0.11	-0.96	-0.84	1.00

Table C-2. Humerus: Pooled Within-Groups Correlation Matrix.

Variable	HML	BUE	MDS	MDM	MDH	EBR	LCS
HML	1.00						
BUE	0.50	1.00					
MDS	0.32	0.38	1.00				
MDM	0.29	0.34	0.41	1.00			
MDH	0.50	0.82	0.32	0.21	1.00		
EBR	0.37	0.55	0.38	0.38	0.49	1.00	
LCS	0.36	0.42	0.71	0.70	0.36	0.48	1.00

Table C-3. Ulna: Pooled Within-Groups Correlation Matrix.

Variable	UML	BOP	MBO	WOP	ORL	OCL	UPL	ULC
UML	1.00							
BOP	0.34	1.00						
MBO	0.18	0.22	1.00					
WOP	0.37	0.34	0.13	1.00				
ORL	0.44	0.37	0.21	0.27	1.00			
OCL	0.27	0.22	0.12	0.21	0.55	1.00		
UPL	0.97	0.31	0.17	0.29	0.41	0.23	1.00	
ULC	0.23	0.32	0.08	0.36	0.27	0.21	0.16	1.00

Table C-4. Femur: Pooled Within-Groups Correlation Matrix.

Variable	FML	FOL	FTL	APD	MLD	APS	MLS	VHD	HHD	APL	APM	FEB	BCB	VDN	CCL	FNA	FCA
FML	1.00																
FOL	0.99	1.00															
FTL	0.96	0.97	1.00														
APD	0.40	0.41	0.45	1.00													
MLD	0.35	0.34	0.40	0.32	1.00												
APS	0.44	0.45	0.48	0.65	0.20	1.00											
MLS	0.34	0.35	0.42	0.53	0.67	0.31	1.00										
VHD	0.54	0.55	0.53	0.40	0.45	0.36	0.43	1.00									
HHD	0.55	0.55	0.53	0.36	0.42	0.31	0.38	0.93	1.00								
APL	0.53	0.52	0.53	0.33	0.34	0.34	0.34	0.69	0.68	1.00							
APM	0.50	0.50	0.53	0.42	0.48	0.40	0.47	0.68	0.67	0.72	1.00						
FEB	0.48	0.48	0.50	0.39	0.40	0.39	0.41	0.72	0.71	0.73	0.72	1.00					
BCB	0.39	0.40	0.41	0.34	0.28	0.32	0.33	0.54	0.53	0.58	0.59	0.72	1.00				
VDN	0.48	0.48	0.51	0.45	0.44	0.41	0.43	0.67	0.63	0.48	0.53	0.54	0.42	1.00			
CCL	0.41	0.44	0.42	0.34	0.37	0.23	0.53	0.36	0.33	0.35	0.34	0.30	0.34	0.30	1.00		
FNA	-0.02	-0.01	-0.17	-0.14	-0.27	-0.11	-0.35	-0.03	-0.01	-0.07	-0.12	-0.05	-0.09	-0.17	-0.27	1.00	
FCA	0.08	0.02	0.01	0.03	0.11	-0.06	0.07	0.02	0.01	0.05	0.07	-0.01	-0.05	0.01	0.14	-0.18	1.00

Table C-5. Tibia: Pooled Within-Groups Correlation Matrix.

Variable	TML	BPE	BDE	APN	MLM	NFL
TML	1.00					
BPE	0.44	1.00				
BDE	0.42	0.71	1.00			
APN	0.44	0.51	0.47	1.00		
MLM	0.26	0.37	0.39	0.27	1.00	
NFL	0.45	0.21	0.19	0.03	-0.05	1.00

Table C-6. All Bones Combined: Pooled Within-Groups Correlation Matrix, Section 1.

Variable	HML	BUE	RML	UML	FML	FOL	FTL	TML	BPE	BDE	BML	CML	MDS	MDM	MDH	EBR	RDH	BOP	MBO
HML	1.00																		
BUE	0.50	1.00																	
RML	0.76	0.38	1.00																
UML	0.77	0.42	0.95	1.00															
FML	0.80	0.44	0.74	0.75	1.00														
FOL	0.80	0.45	0.75	0.75	0.99	1.00													
FTL	0.80	0.45	0.77	0.78	0.96	0.96	1.00												
TML	0.75	0.37	0.86	0.86	0.78	0.87	0.81	1.00											
BPE	0.43	0.69	0.43	0.46	0.48	0.48	0.47	0.46	1.00										
BDE	0.37	0.70	0.36	0.36	0.37	0.37	0.38	0.33	0.76	1.00									
BML	0.76	0.40	0.85	0.86	0.80	0.81	0.84	0.95	0.45	0.34	1.00								
CML	0.50	0.40	0.49	0.46	0.54	0.54	0.54	0.48	0.41	0.38	0.53	1.00							
MDS	0.28	0.41	0.23	0.27	0.23	0.23	0.25	0.28	0.33	0.35	0.28	0.22	1.00						
MDM	0.35	0.33	0.25	0.26	0.35	0.34	0.37	0.28	0.29	0.31	0.26	0.25	0.43	1.00					
MDH	0.57	0.84	0.41	0.40	0.47	0.46	0.46	0.38	0.63	0.65	0.39	0.41	0.43	0.40	1.00				
EBR	0.31	0.53	0.30	0.34	0.33	0.33	0.34	0.23	0.53	0.63	0.27	0.32	0.35	0.37	0.45	1.00			
RDH	0.47	0.61	0.47	0.47	0.36	0.36	0.35	0.38	0.54	0.55	0.35	0.25	0.35	0.31	0.62	0.48	1.00		
BOP	0.37	0.40	0.37	0.38	0.35	0.35	0.39	0.28	0.32	0.36	0.32	0.19	0.16	0.43	0.41	0.52	0.43	1.00	
MBO	0.26	0.27	0.22	0.23	0.21	0.21	0.22	0.13	0.21	0.21	0.17	0.05	0.08	0.02	0.23	0.24	0.34	0.22	1.00
WOP	0.30	0.41	0.31	0.33	0.37	0.37	0.41	0.35	0.36	0.38	0.36	0.38	0.28	0.29	0.34	0.41	0.31	0.41	0.19
ORL	0.37	0.43	0.31	0.38	0.30	0.31	0.28	0.36	0.42	0.43	0.31	0.10	0.20	0.18	0.41	0.28	0.53	0.28	0.27
OCL	0.37	0.49	0.26	0.29	0.26	0.26	0.25	0.29	0.32	0.38	0.26	0.21	0.19	0.17	0.49	0.12	0.56	0.20	0.18
APD	0.50	0.39	0.45	0.45	0.46	0.47	0.49	0.52	0.43	0.40	0.47	0.31	0.47	0.61	0.47	0.24	0.40	0.34	0.05
MLD	0.26	0.36	0.31	0.29	0.35	0.36	0.45	0.32	0.34	0.44	0.35	0.31	0.32	0.35	0.29	0.40	0.20	0.37	0.08
APS	0.45	0.25	0.46	0.46	0.43	0.43	0.46	0.47	0.37	0.31	0.39	0.30	0.32	0.39	0.35	0.15	0.34	0.26	-0.01
MLS	0.50	0.42	0.43	0.45	0.47	0.29	0.56	0.48	0.40	0.49	0.50	0.40	0.33	0.51	0.41	0.38	0.30	0.34	0.09
VHD	0.51	0.71	0.51	0.55	0.56	0.56	0.55	0.51	0.75	0.75	0.53	0.51	0.32	0.33	0.67	0.52	0.58	0.42	0.27
HHD	0.50	0.73	0.49	0.52	0.58	0.58	0.56	0.49	0.74	0.71	0.50	0.50	0.30	0.33	0.67	0.47	0.55	0.42	0.28
APL	0.41	0.62	0.36	0.39	0.50	0.49	0.49	0.48	0.75	0.65	0.45	0.37	0.31	0.23	0.64	0.41	0.52	0.30	0.12

Table C-6 (continued).

Variable	HML	BUE	RML	UML	FML	FOL	FTL	TML	BPE	BDE	BML	CML	MDS	MDM	MDH	EBR	RDH	BOP	MBO
APM	0.47	0.62	0.50	0.51	0.51	0.50	0.54	0.56	0.72	0.67	0.55	0.41	0.28	0.30	0.58	0.41	0.43	0.34	0.09
APN	0.40	0.34	0.42	0.38	0.38	0.38	0.43	0.50	0.43	0.41	0.45	0.29	0.28	0.33	0.34	0.13	0.25	0.17	0.02
MLM	0.34	0.40	0.31	0.28	0.38	0.39	0.35	0.37	0.50	0.48	0.37	0.34	0.35	0.27	0.38	0.33	0.32	0.28	0.10
NFL	0.41	0.27	0.46	0.48	0.42	0.42	0.44	0.47	0.22	0.15	0.51	0.24	0.29	0.26	0.29	0.31	0.25	0.26	0.18
SML	0.49	0.49	0.56	0.54	0.45	0.46	0.47	0.45	0.38	0.46	0.51	0.51	0.20	0.30	0.39	0.54	0.44	0.48	0.24
SMB	0.41	0.38	0.44	0.43	0.41	0.41	0.41	0.40	0.33	0.30	0.35	0.47	0.24	0.31	0.36	0.18	0.35	0.22	0.12
SLS	0.46	0.36	0.53	0.52	0.47	0.47	0.49	0.49	0.35	0.30	0.45	0.51	0.27	0.33	0.33	0.28	0.35	0.30	0.11
SSL	0.34	0.27	0.29	0.28	0.28	0.27	0.30	0.33	0.04	0.14	0.35	0.26	0.04	0.18	0.18	0.16	0.16	0.21	0.09
ISL	0.41	0.36	0.49	0.49	0.38	0.38	0.38	0.38	0.38	0.44	0.44	0.47	0.17	0.26	0.31	0.51	0.38	0.45	0.21
GCB	0.38	0.54	0.35	0.36	0.35	0.36	0.35	0.33	0.45	0.42	0.32	0.31	0.30	0.23	0.52	0.33	0.46	0.33	0.07
GCH	0.30	0.59	0.29	0.33	0.25	0.26	0.27	0.25	0.54	0.59	0.29	0.33	0.26	0.16	0.55	0.52	0.46	0.40	0.18
GIL	0.54	0.40	0.61	0.61	0.56	0.57	0.55	0.56	0.44	0.41	0.56	0.47	0.31	0.27	0.36	0.41	0.44	0.32	0.14
UPL	0.74	0.33	0.95	0.97	0.71	0.72	0.74	0.85	0.39	0.30	0.85	0.43	0.22	0.22	0.34	0.26	0.40	0.32	0.19
FEB	0.39	0.70	0.35	0.40	0.47	0.47	0.49	0.41	0.85	0.76	0.43	0.43	0.37	0.30	0.65	0.63	0.56	0.36	0.19
BCB	0.39	0.68	0.31	0.36	0.45	0.45	0.46	0.33	0.78	0.59	0.38	0.39	0.38	0.38	0.63	0.54	0.49	0.36	0.15
LCS	0.44	0.52	0.36	0.38	0.43	0.42	0.45	0.42	0.44	0.47	0.42	0.37	0.75	0.70	0.54	0.47	0.43	0.46	0.08
MCS	0.44	0.49	0.40	0.38	0.38	0.38	0.37	0.38	0.44	0.35	0.37	0.26	0.40	0.36	0.50	0.29	0.51	0.30	0.19
ULC	0.24	0.53	0.23	0.24	0.32	0.31	0.32	0.23	0.51	0.53	0.24	0.28	0.40	0.39	0.51	0.43	0.44	0.41	0.13
VDN	0.61	0.58	0.61	0.60	0.60	0.59	0.63	0.57	0.60	0.61	0.54	0.42	0.32	0.45	0.63	0.48	0.50	0.48	0.22
CCL	0.52	0.33	0.45	0.46	0.57	0.69	0.58	0.51	0.30	0.31	0.50	0.33	0.23	0.40	0.35	0.27	0.33	0.31	0.15
FNA	-0.16	-0.15	-0.19	-0.22	-0.03	-0.03	-0.19	-0.21	-0.05	-0.08	-0.19	-0.09	-0.05	-0.19	-0.06	-0.11	-0.01	-0.12	-0.08
FCA	0.16	-0.01	0.11	0.11	0.24	0.18	0.17	0.14	0.03	0.19	0.12	0.19	0.03	0.19	0.09	0.08	0.03	0.08	-0.09
LSA	-0.05	0.02	-0.01	-0.02	-0.09	-0.10	-0.08	-0.09	0.02	0.12	-0.01	0.07	-0.09	0.04	0.01	0.21	0.03	0.21	0.12
VSA	0.09	-0.04	0.09	0.10	0.15	0.05	0.12	0.15	0.13	-0.05	0.12	-0.09	0.09	-0.10	-0.03	-0.02	0.01	-0.12	-0.02
ISA	-0.05	0.03	-0.09	-0.11	-0.07	-0.07	-0.05	-0.07	-0.05	-0.07	-0.13	-0.05	-0.02	0.06	0.05	-0.23	-0.05	-0.11	-0.11
SSA	0.08	-0.08	0.07	0.06	0.03	0.02	0.02	0.08	-0.02	0.03	0.20	0.08	-0.05	0.06	-0.06	-0.01	-0.03	0.08	-0.01
CSA	0.14	-0.01	0.05	0.04	0.08	0.07	0.08	0.14	-0.13	-0.05	0.14	0.05	-0.08	0.05	-0.03	-0.09	-0.08	0.04	-0.01
MSA	-0.11	0.06	-0.07	-0.06	-0.05	-0.04	-0.04	-0.11	0.06	-0.01	-0.12	-0.08	0.07	-0.06	0.05	0.03	0.05	-0.06	0.07

Table C-7. All Bones Combined: Pooled Within-Groups Correlation Matrix, Sextion 2.

Variable	WOP	ORL	OCL	APD	MLD	APS	MLS	VHD	HHD	APL	APM	APN	MLM	NFL	SML	SMB	SLS	SSL	ISL
HML																			
BUE																			
RML																			
UML																			
FML																			
FOL																			
FTL																			
TML																			
BPE																			
BDE																			
BML																			
CML																			
MDS																			
MDM																			
MDH																			
EBR																			
RDH																			
BOP																			
MBO																			
WOP	1.00																		
ORL	0.21	1.00																	
OCL	0.10	0.66	1.00																
APD	0.23	0.38	0.40	1.00															
MLD	0.34	0.14	0.14	0.37	1.00														
APS	0.23	0.29	0.23	0.66	0.22	1.00													
MLS	0.36	0.28	0.28	0.58	0.66	0.40	1.00												
VHD	0.37	0.45	0.50	0.48	0.47	0.42	0.48	1.00											
HHD	0.39	0.46	0.52	0.44	0.45	0.36	0.44	0.95	1.00										
APL	0.35	0.50	0.41	0.38	0.31	0.35	0.34	0.66	0.68	1.00									

Table C-7 (continued).

Variable	WOP	ORL	OCL	APD	MLD	APS	MLS	VHD	HHD	APL	APM	APN	MLM	NFL	SML	SMB	SLS	SSL	ISL
APM	0.39	0.40	0.39	0.50	0.48	0.42	0.48	0.72	0.70	0.70	1.00								
APN	0.26	0.17	0.15	0.53	0.38	0.52	0.46	0.41	0.37	0.36	0.52	1.00							
MLM	0.35	0.31	0.18	0.41	0.30	0.42	0.26	0.47	0.49	0.43	0.38	0.28	1.00						
NFL	0.19	0.24	0.16	0.27	0.17	0.17	0.33	0.29	0.28	0.23	0.30	0.03	-0.01	1.00					
SML	0.37	0.26	0.15	0.27	0.38	0.18	0.39	0.51	0.48	0.33	0.42	0.36	0.33	0.22	1.00				
SMB	0.21	0.16	0.25	0.36	0.30	0.34	0.37	0.41	0.40	0.34	0.36	0.37	0.22	0.13	0.34	1.00			
SLS	0.24	0.20	0.21	0.39	0.39	0.39	0.45	0.42	0.41	0.29	0.34	0.27	0.34	0.20	0.44	0.79	1.00		
SSL	0.27	0.98	0.05	0.24	0.19	0.17	0.28	0.16	0.17	0.17	0.21	0.24	0.20	0.13	0.55	0.27	0.35	1.00	
ISL	0.29	0.21	0.10	0.19	0.27	0.11	0.31	0.49	0.44	0.24	0.36	0.29	0.21	0.23	0.86	0.19	0.21	0.25	1.00
GCB	0.30	0.33	0.34	0.37	0.29	0.35	0.27	0.55	0.51	0.43	0.41	0.33	0.32	0.26	0.39	0.36	0.34	0.17	0.29
GCH	0.25	0.38	0.25	0.26	0.35	0.23	0.32	0.63	0.57	0.46	0.45	0.26	0.34	0.15	0.50	0.10	0.20	0.13	0.18
GIL	0.23	0.29	0.28	0.45	0.33	0.39	0.39	0.52	0.50	0.40	0.45	0.37	0.40	0.30	0.66	0.54	0.57	0.29	0.55
UPL	0.23	0.32	0.25	0.43	0.72	0.46	0.42	0.48	0.45	0.32	0.47	0.38	0.23	0.45	0.49	0.42	0.51	0.27	0.44
FEB	0.33	0.48	0.40	0.38	0.40	0.31	0.44	0.77	0.78	0.78	0.70	0.33	0.46	0.28	0.46	0.30	0.32	0.01	0.43
BCB	0.38	0.38	0.41	0.39	0.31	0.25	0.49	0.59	0.59	0.59	0.55	0.26	0.28	0.34	0.37	0.19	0.21	0.10	0.34
LCS	0.31	0.28	0.29	0.65	0.43	0.47	0.49	0.47	0.45	0.42	0.43	0.40	0.51	0.27	0.39	0.42	0.43	0.21	0.31
MCS	0.24	0.38	0.33	0.42	0.21	0.25	0.20	0.43	0.43	0.38	0.40	0.22	0.40	0.23	0.25	0.41	0.37	0.10	0.22
ULC	0.44	0.26	0.28	0.44	0.36	0.32	0.30	0.51	0.55	0.46	0.43	0.28	0.51	0.11	0.32	0.26	0.22	0.18	0.29
VDN	0.42	0.34	0.39	0.51	0.44	0.50	0.49	0.72	0.71	0.56	0.64	0.51	0.38	0.28	0.47	0.46	0.50	0.21	0.38
CCL	0.31	0.25	0.25	0.44	0.42	0.27	0.62	0.36	0.33	0.37	0.40	0.23	0.23	0.33	0.32	0.26	0.32	0.23	0.26
FNA	-0.99	0.05	0.03	-0.17	-0.36	-0.17	-0.41	-0.06	-0.02	0.01	-0.18	-0.12	0.12	-0.16	-0.11	-0.06	-0.12	-0.11	-0.12
FCA	0.09	0.04	0.05	0.08	0.09	-0.02	0.13	0.01	0.01	0.13	0.11	-0.03	-0.05	0.11	0.07	0.15	0.06	0.14	0.14
LSA	0.09	-0.02	-0.14	-0.19	-0.02	-0.22	-0.04	0.06	0.02	-0.10	-0.01	-0.03	-0.12	-0.01	0.36	-0.37	-0.34	-0.01	0.63
VSA	-0.09	0.08	0.11	0.18	0.02	0.18	0.01	-0.01	0.01	0.09	0.04	0.01	0.20	0.12	-0.11	-0.11	0.06	-0.01	-0.30
ISA	-0.01	-0.06	0.05	-0.01	0.01	0.03	0.03	-0.06	-0.03	0.03	-0.03	0.03	-0.10	-0.13	-0.32	0.62	0.36	0.01	-0.42
SSA	0.01	-0.08	-0.10	0.03	-0.09	0.01	0.04	0.05	-0.01	-0.09	0.02	0.07	-0.10	0.09	0.08	-0.09	-0.20	0.20	0.44
CSA	0.09	-0.05	-0.08	0.10	-0.03	0.07	0.09	-0.03	-0.06	-0.04	0.01	0.06	0.01	0.08	0.06	-0.01	-0.01	0.70	0.09
MSA	-0.04	0.08	0.11	-0.06	0.07	-0.03	-0.06	-0.03	0.03	0.08	-0.02	-0.07	0.07	-0.09	-0.08	0.07	0.15	-0.38	-0.36

Table C-8. All Bones Combined: Pooled Within-Groups Correlation Matrix, Section 3.

Variable	GCB	GCH	GIL	UPL	FEB	BCB	LCS	MSC	ULC	VDN	CCL	FNA	FAC	LSA	VSA	ISA	SSA	CSA	MSA
APM																			
APN																			
MLM																			
NFL																			
SML																			
SMB																			
SLS																			
SSL																			
ISL																			
GCB	1.00																		
GCH	0.58	1.00																	
GIL	0.47	0.41	1.00																
UPL	0.33	0.27	0.59	1.00															
FEB	0.46	0.56	0.42	0.33	1.00														
BCB	0.39	0.48	0.41	0.28	0.69	1.00													
LCS	0.39	0.34	0.46	0.32	0.48	0.49	1.00												
MCS	0.40	0.29	0.37	0.38	0.38	0.31	0.53	1.00											
ULC	0.40	0.36	0.29	0.14	0.54	0.48	0.54	0.35	1.00										
VDN	0.46	0.44	0.55	0.56	0.59	0.48	0.49	0.47	0.47	1.00									
CCL	0.20	0.17	0.36	0.44	0.32	0.38	0.34	0.18	0.22	0.38	1.00								
FNA	-0.09	-0.11	-0.07	-0.23	-0.05	-0.15	-0.07	0.12	-0.09	-0.15	-0.25	1.00							
FCA	0.01	-0.04	0.03	0.12	0.07	0.05	0.13	0.03	0.19	0.07	0.32	-0.20	1.00						
LSA	-0.12	0.17	-0.28	-0.05	0.11	0.01	-0.08	-0.11	0.06	-0.07	-0.03	-0.06	0.11	1.00					
VSA	0.13	0.07	0.49	0.13	-0.04	0.11	0.05	0.03	-0.06	0.08	0.08	0.07	-0.18	-0.70	1.00				
ISA	-0.05	-0.31	-0.31	-0.12	-0.07	-0.17	0.03	0.10	-0.01	-0.01	-0.07	0.01	0.11	-0.32	-0.44	1.00			
SSA	-0.08	-0.01	-0.04	0.01	-0.02	-0.01	-0.01	-0.01	0.07	-0.03	0.05	-0.01	0.27	0.54	-0.40	-0.17	1.00		
CSA	-0.09	-0.09	-9.07	0.06	-0.11	-0.06	0.03	0.01	0.08	-0.03	0.10	-0.08	0.24	0.16	-0.18	0.02	0.71	1.00	
MSA	0.09	0.04	0.05	-0.08	0.05	0.03	-0.01	0.01	-0.08	0.03	-0.07	0.10	-0.28	-0.45	0.35	0.12	-0.97	-0.85	1.00

APPENDIX D

PRINCIPAL COMPONENT MATRICES

Table D-1. Scapula: Varimax Rotated Principal Component Matrix.

Variable	1	2	3	4	Communality
SML	0.88	0.18	-0.08	-0.20	0.86
SMB	0.54	0.05	0.77	0.12	0.90
SLS	0.60	0.04	0.60	0.25	0.80
SSL	0.38	0.69	0.19	0.21	0.70
ISL	0.76	0.19	-0.26	-0.51	0.94
GCB	0.63	-0.06	0.18	-0.03	0.43
GCH	0.63	-0.04	0.01	-0.04	0.40
GIL	0.83	0.06	0.01	0.40	0.87
LSA	0.14	0.15	-0.39	-0.88	0.97
VSA	0.04	-0.13	-0.25	0.95	0.98
ISA	-0.30	-0.05	0.94	-0.09	0.99
SSA	0.01	0.76	-0.19	-0.46	0.83
CSA	-0.07	0.96	0.08	0.03	0.96
MSA	0.02	-0.90	0.11	0.33	0.93
Eigenvalue	3.77	2.95	2.26	2.59	
Percent of Trace	27.0	21.0	16.0	19.0	

Table D-2. Humerus: Varimax Rotated Principal Component Matrix.

Variable	1	2	Communality
HML	0.68	0.21	0.50
BUE	0.88	0.21	0.83
MDS	0.22	0.78	0.66
MDM	0.18	0.79	0.66
MDH	0.90	0.14	0.83
EBR	0.60	0.41	0.53
LCS	0.25	0.91	0.89
Eigenvalue	2.57	2.34	
Percent of Trace	37.0	33.0	

Table D-3. Ulna: Varimax Rotated Principal Component Matrix.

Variable	1	2	3	Communality
UML	0.21	0.94	0.22	0.98
BOP	0.61	0.20	0.29	0.49
MBO	0.10	0.12	0.37	0.17
WOP	0.74	0.24	0.06	0.61
ORL	0.21	0.26	0.79	0.74
OCL	0.08	0.03	0.86	0.76
UPL	0.13	0.96	0.19	0.97
ULC	0.80	-0.03	0.14	0.66
Eigenvalue	1.67	1.99	1.71	
Percent of Trace	21.0	25.0	21.0	

Table D-4. Femur: Varimax Rotated Principal Component Matrix.

Variable	1	2	3	4	Communality
FML	0.34	0.10	0.92	0.11	0.98
FOL	0.34	0.09	0.92	0.15	0.98
FTL	0.33	0.19	0.87	0.20	0.94
APD	0.24	0.36	0.23	0.70	0.73
MLD	0.39	0.64	0.14	0.05	0.28
APS	0.21	0.14	0.32	0.75	0.72
MLS	0.32	0.73	0.12	0.28	0.74
VHD	0.85	0.13	0.26	0.10	0.82
HHD	0.85	0.08	0.28	0.05	0.80
APL	0.79	0.10	0.28	0.03	0.72
APM	0.78	0.24	0.22	0.13	0.72
FEB	0.86	0.10	0.17	0.16	0.80
BCB	0.72	0.10	0.11	0.19	0.57
VDN	0.58	0.26	0.24	0.30	0.55
CCL	0.22	0.57	0.35	0.02	0.50
FNA	0.06	-0.72	0.05	-0.03	0.53
FCA	-0.04	0.43	0.14	-0.52	0.48
Eigenvalue	5.00	2.36	3.15	1.66	
Percent of Trace	29.0	14.0	19.0	10.0	

Table D-5. Tibia: Varimax Rotated Principal Component Matrix.

Variable	1	2	Communality
TML	0.47	0.69	0.69
BPE	0.80	0.28	0.71
BDE	0.80	0.25	0.70
APN	0.73	0.13	0.54
MLM	0.70	-0.17	0.51
NFL	-0.06	0.92	0.85
Eigenvalue	2.50	1.51	
Percent of Trace	42.0	25.0	

Table D-6. All Bones Combined: Varimax Rotated Principal Component Matrix.

Variable	1	2	3	4	5	6	7	8	9	10	11	12	Communality
HML	0.24	0.76	0.10	0.10	0.17	0.12	0.09	0.22	0.03	0.03	0.12	-0.04	0.77
BUE	0.76	0.17	0.01	0.17	0.18	0.12	-0.03	0.20	0.01	0.03	0.20	-0.15	0.79
RML	0.18	0.88	0.02	0.10	0.10	0.21	-0.10	0.12	-0.04	0.08	0.04	-0.03	0.90
UML	0.22	0.87	0.02	0.07	0.09	0.19	-0.09	0.15	-0.03	0.11	0.04	-0.08	0.90
FML	0.31	0.83	0.01	0.04	0.12	0.04	0.28	-0.01	0.07	-0.07	0.16	0.04	0.92
FOL	0.31	0.84	-0.01	0.03	0.11	0.04	0.26	0.01	0.08	-0.16	0.16	0.05	0.92
FTL	0.30	0.84	-0.01	0.05	0.13	0.02	0.21	-0.03	0.05	0.10	0.19	0.04	0.92
TML	0.23	0.88	0.11	0.05	0.12	0.03	-0.01	0.07	0.07	0.10	0.01	0.05	0.89
BPE	0.84	0.28	-0.07	0.01	0.13	0.02	-0.04	0.02	-0.04	-0.01	0.01	0.07	0.82
BDE	0.8	0.12	-0.01	0.02	0.14	0.16	0.02	0.10	-0.09	0.12	0.09	0.12	0.77
BML	0.26	0.88	0.11	0.01	0.10	0.09	0.02	0.01	0.04	0.08	0.07	-0.01	0.89
CML	0.38	0.44	0.05	0.28	0.07	0.33	0.23	-0.16	-0.07	-0.03	-0.16	0.02	0.64
MDS	0.30	0.11	-0.05	0.02	0.74	0.02	-0.08	-0.07	0.08	0.02	0.01	-0.18	0.70
MDM	0.14	0.15	0.01	0.10	0.73	0.10	0.26	0.11	-0.12	0.22	0.07	0.07	0.74
MDH	0.70	0.21	0.01	0.16	0.28	0.03	0.02	0.26	-0.02	0.01	0.11	-0.13	0.73
EBR	0.53	0.10	-0.10	-0.09	0.26	0.41	0.10	-0.06	-0.09	0.10	0.31	-0.20	0.71
RDH	0.48	0.22	-0.04	0.10	0.24	0.22	-0.08	0.53	-0.06	-0.06	0.16	-0.11	0.73
BOP	0.24	1.20	0.01	-0.01	0.31	0.32	0.08	0.20	-0.19	0.13	0.45	0.02	0.59
MBO	0.13	0.18	-0.03	-0.06	-0.07	0.07	-0.25	0.29	-0.13	-0.01	-0.53	-0.22	0.55
WOP	0.36	0.23	0.08	0.04	0.14	0.01	0.02	-0.12	-0.04	0.09	0.60	0.07	0.60
ORL	0.38	0.20	-0.04	-0.07	0.07	0.02	0.03	0.70	0.04	-0.05	0.12	0.04	0.71
OCL	0.39	0.13	-0.05	0.09	0.06	-0.03	0.11	0.76	0.10	-0.01	-0.07	0.01	0.78
APD	0.26	0.36	0.11	0.03	0.61	-0.02	0.03	0.28	0.16	0.22	-0.06	0.26	0.81
MLD	0.36	0.18	-0.10	0.11	0.20	0.17	0.15	-0.14	0.05	0.54	0.23	0.18	0.67
APS	0.21	0.42	0.08	0.07	0.43	-0.08	-0.19	0.16	0.15	0.16	-0.10	0.38	0.68
MLS	0.32	0.34	0.04	0.09	0.28	0.09	0.23	0.08	0.05	0.60	0.11	0.12	0.77
VHD	0.78	0.35	0.01	0.08	0.10	0.17	-0.04	0.18	-0.06	0.06	0.04	0.09	0.83
HHD	0.79	0.34	-0.03	0.10	0.07	0.12	0.01	0.17	-0.03	0.01	0.10	0.08	0.81
APL	0.79	0.26	-0.01	0.07	0.05	-0.07	0.14	0.13	0.11	-0.05	0.03	0.07	0.76
APM	0.72	0.38	0.05	0.06	0.08	-0.01	0.01	0.07	0.01	0.21	-0.03	0.15	0.74
APN	0.31	0.37	0.10	0.14	0.24	0.04	-0.23	-0.02	-0.03	0.26	-0.11	0.49	0.70
MLM	0.43	0.21	-0.01	-0.02	0.34	0.13	-0.01	-0.06	0.22	-0.27	0.25	0.41	0.70
NFL	0.16	0.47	0.07	-0.09	0.20	-0.01	0.02	0.03	0.07	0.17	0.03	-0.60	0.70
SML	0.31	0.36	0.09	0.05	0.06	0.77	0.03	0.03	-0.13	0.07	0.23	0.07	0.91
SMB	0.22	0.31	-0.02	0.83	0.19	0.17	0.06	0.05	0.06	0.03	-0.06	0.05	0.91
SLS	0.17	0.41	0.08	0.65	0.19	0.29	0.01	0.03	0.18	0.11	0.09	0.09	0.81
SSL	0.04	0.19	0.63	0.20	-0.02	0.32	0.08	0.02	0.27	0.11	0.35	0.09	0.83
ISL	0.30	0.33	0.18	-0.15	0.09	0.70	0.03	0.01	-0.44	0.03	0.01	0.01	0.96
GCB	0.50	0.17	0.01	0.16	0.20	0.27	-0.17	0.16	0.19	0.06	-0.03	0.08	0.52
GCH	0.64	0.07	-0.02	-0.14	0.06	0.42	-0.16	0.12	0.02	0.13	0.02	-0.04	0.68
GIL	0.30	0.49	-0.02	0.08	0.19	0.59	-0.01	0.08	0.39	0.01	-0.09	0.03	0.89
UPL	0.13	0.89	0.03	0.08	0.06	0.19	-0.11	0.14	-0.01	0.13	-0.04	-0.06	0.90
FEB	0.87	0.21	-0.07	-0.01	0.12	0.09	0.08	0.06	-0.07	0.01	0.04	-0.01	0.84
BCB	0.71	0.18	-0.03	-0.12	0.22	0.06	0.18	0.08	0.09	0.14	0.16	-0.20	0.70
LCS	0.35	0.21	0.02	0.13	0.80	0.15	0.09	0.03	0.05	0.03	0.09	0.02	0.87
MCS	0.33	0.28	0.02	0.23	0.45	0.04	-0.11	0.23	0.01	-0.29	0.09	-0.12	0.62
ULC	0.56	0.02	0.12	0.04	0.41	0.06	0.12	0.02	-0.03	-0.03	0.25	0.14	0.60
VDN	0.53	0.46	-0.04	0.17	0.24	0.13	-0.07	0.17	-0.01	0.14	0.13	0.11	0.68
CCL	0.19	0.45	0.02	-0.04	0.17	0.04	0.53	0.15	0.08	0.31	0.13	0.03	0.70
FNA	0.01	-0.12	-0.07	-0.01	-0.03	-0.01	0.01	0.03	0.06	-0.82	0.01	0.13	0.71
FCA	0.01	0.10	0.24	0.11	0.06	0.01	0.69	0.03	-0.14	0.06	-0.11	-0.10	0.60
LSA	0.06	-0.07	0.23	-0.36	-0.07	0.27	0.04	-0.05	-0.82	0.01	0.09	-0.01	0.95
VSA	-0.02	0.15	-0.19	-0.30	0.04	0.06	-0.08	0.05	0.88	-0.03	-0.09	-0.01	0.95
ISA	-0.04	-0.10	-0.05	0.86	0.01	-0.43	0.06	0.01	-0.14	0.01	0.01	0.03	0.97
SSA	-0.01	0.08	0.81	-0.19	0.04	0.06	0.05	-0.05	-0.41	-0.01	-0.18	-0.04	0.91
CSA	-0.09	0.06	0.96	0.05	-0.01	-0.05	0.09	-0.02	0.05	0.02	0.14	0.02	0.97
MSA	0.04	-0.07	-0.91	0.12	-0.03	-0.03	-0.07	0.04	0.29	-0.01	0.09	0.02	0.95
Eigenvalue	10.42	10.00	3.14	2.69	3.86	2.97	1.57	2.14	2.54	2.07	1.75	1.45	
Percent of Trace	18.0	18.0	6.0	5.0	7.0	5.0	3.0	4.0	5.0	4.0	3.0	3.0	

VITA

Terry Stewert Zobeck was born on November 5, 1953, in Syracuse, New York. His family moved to Cleveland, Ohio, in 1958 where he graduated from John Marshall High School in June 1971. The following fall Terry entered the Cleveland State University and in June 1975 he received a Bachelor of Arts degree in Anthropology.

Terry worked for Northern Record Sales in Cleveland for a year and a half before enrolling at The University of Tennessee, Knoxville, in the winter of 1977. In August of 1980 he received a Master of Arts degree. The following fall Terry entered the doctoral program in Anthropology at The University of Tennessee, Knoxville.

Terry is a member of the American Association of Physical Anthropologists, American Anthropological Association, and the American Dermatoglyphics Association. he is also a member of Sigma Xi, the honors society.

His interest outside of Anthropology included reading and music.

Terry is married to the former Sandra Houghton of Cleveland, Ohio.