NORTHERN ILLINOIS UNIVERSITY

FRONTAL SINUS MORPHOLOGY: AN ANALYSIS OF CRANIOMETRIC AND ENVIRONMENTAL VARIABLES ON THE MORPHOLOGY OF MODERN HUMAN FRONTAL SINUS PATTERNS

A THESIS SUBMITTED TO THE GRADUATE SCHOOL IN

PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER OF ARTS

DEPARTMENT OF ANTHROPOLOGY

BY

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DEKALB, ILLINOIS

December, 1995

ABSTRACT

Although occasionally studied, the frontal sinuses have always been poorly understood both in their function and variation. It was the purpose of this study to systematically investigate the range of variation and possible associated factors in frontal sinus size. Samples were drawn from regions that represent five distinct modern human populations; Papua New Guinea, the Philippine islands, Baghdad and Kish in Iraq, Marquez Peru, and Egypt.

A variety of measurements and data were collected for each individual. Twenty-nine cranial measurements were used to place each individual within the context of traditional craniometrics. Sinus data was derived from anterior-posterior radiographs which were digitized and measured on an IBM compatible PC. Finally, climate data was obtained for each region represented in the study.

Statistically significant frontal sinus size differences were found, with the Baghdad Iraq and Egypt showing larger frontal sinus size than the Papua New Guinea, Kish Iraq, Philippine, and Peruvian samples. Craniometric data failed to statistically correlate with sinus size, prompting exploration for other potential factors. Climate data, and specifically differential seasonal variation in temperature, was found to significantly correlate with

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frontal sinus size among all the groups except the Kish and Peruvian samples.

This study demonstrated that frontal sinus size does differ between certain modern human populations. Further, craniometrics failed to provide the necessary correlation to explain the observed differences. Finally, a strong experimental positive correlation was found between annual seasonal temperature fluctuation and frontal sinus size.

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Acknowledgments

When I decided to pursue a degree in the field of anthropology in the summer of 1992, I had no idea what lay ahead. The last three years have been filled with challenges, opportunities, and most of all, intellectual fulfillment. I owe each individual named a great deal, more than a few words can convey.

Though any diploma is ultimately issued by a university, the true credit for conferring its knowledge lies in the faculty. It has been my privilege to work with some of the finest scientists in the world. Dr. Fred Smith has offered the kind of encouragement, advice, and mentoring every graduate student dreams about. I am proud to have had the opportunity to work under his guidance. Dr. Dan Gebo can be credited with sparking my interest in physical anthropology. Since the first day of ANTH 240 in the spring of 1993, he has challenged and nurtured my interests in the field. Thanks to Dr. Maria Smith, I discovered that the study of modern human populations can be as intriguing as that of fossils. The art and science of statistics is a formidable hurdle in any study. Thanks to Dr. Michael Parrish and Dr. Rani Alexander for giving me the tools and advice to successfully implement statistics in my work.

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The camaraderie and friendship I have gained while at NIU will follow and give me support in years to come. I thank my contemporaries Rolf Quam, George Higginbotham, Brian Lesley, and Karen Leslie for the countless hours spent in study and recreation which provided me with the confidence I needed in my work. Thank you Chris Vinyard and Trish Sothman for providing me with advice and an excellent example of scientific scholarship. To Mark Selquist, Trent Stockton, Ali Kaylor, and the rest of the anthropology students at NIU, I am grateful for your advice, encouragement, and most of all, friendship.

The work represented in this thesis would not have been possible without the aid of Dr. Jonathan Haas, Christine Gross, Will Grewe-Mullins and the anthropology department at the Field Museum of Natural History in Chicago. Thank you for your help and patience. In addition, I would like to thank Patricia Dinges and Todd Adee of NIU’s University Health Services Radiology section. Without their help, the extensive use of radiograph technology in this study would have been impossible.

Finally, none of this would be possible without the support of my loving wife, Susan, and my parents. Without their understanding, love, and devotion, I would have surely faltered long ago. It is to you that I dedicate my work at NIU and this thesis.

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CHAPTER 1

INTRODUCTION

The question of why paranasal, and specifically the frontal, sinuses exist dates back to the time of Galen in 130-201AD, who referred to the frontal sinuses as "...[the] porosity of the bones of the head" (Blanton and Biggs, 1969). The physiological purpose of frontal sinuses is still very poorly understood, and attempts to link frontal sinus patterns with specific influences, such as the environment, have been inconclusive. Several functional theories that try to explain the existence of frontal sinuses have met with varying levels of acceptance among researchers (Table 1).

Table 1. Theories Concerning the Function of The Frontal Sinuses (Blanton and Biggs, 1969).

1. Impart resonance to the voice.
2. Humidify and warm inspired air.
3. Increase the area of the olfactory membrane.
4. Absorb shock applied to the head for protection of the sensory organs.
5. Secrete mucus for keeping the nasal chambers moist.
6. Thermally insulate the nervous centers.
7. Aid facial growth and architecture.
8. Lighten the bones of the skull for maintenance of proper balance.

In addition, variability due to the effects of age and pathology is also recognized (Table 2). However, no one theory or explanation for variation has emerged as dominant (Blanton and Biggs, 1969; Koertvelyessy, 1972).

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Table 2. Variations Due to Pathology (Schuller, 1943).

1. Enlargement due to the thinning of frontal sinus walls which is in turn due to old age.
2. Post-menopausal symmetrical hyperostosis on the inner surface of the forehead causing reduction.
3. Chronic inflammatory conditions (i.e., sinusitis) causing the thinning or thickening of the compact lamina and subsequent enlargement or reduction of the frontal sinus.
4. Injuries, tumors, and obstruction of the fronto-nasal duct causing frontal sinus enlargement.

Also, variation has been suggested to be attributable to both sex (Buckland-Wright, 1970) and biological affinity (Brothwell, et al., 1968).

The importance of understanding frontal sinuses lies on two fronts. The first front is primarily paleontological. Researchers have offered a variety of hypotheses concerning the development of the supraorbital region. Two of these are particularly prominent in the literature. The first is a biomechanical hypothesis that proposes the supraorbital region's ability to resist strain and stress resulting from masticatory action (Oyen, et al., 1979; Russell, 1983). The second proposes that the supraorbital region serves as a structural component that bridges the brain case with the face (Moss and Young, 1960). If it can be shown that supraorbital development is even partially correlated with

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sinus size, and that sinuses are correlated with geographic environmental variables, it adds an additional factor to the puzzle of the meaning of supraorbital development. As such, it brings us a step closer to understanding the basis of variation in the supraorbital region of earlier humans.

The second front is primarily clinical. If the frontal sinuses can be placed into an adaptive context, their drawback, specifically chronic sinusitis, may be partially understood. Since sinusitis affects more than 31 million people in the US and is the most common health care complaint in this country (Shankar, et al. 1994: 35), any additional information on the adaptive significance of this structure may certainly be useful.

The purpose of this thesis is to conduct a morphological survey of six skeletal populations in order to evaluate the impact of cranial variation and climatic affinity on the size of the frontal sinus. The null hypothesis is that no relationship exists between frontal sinus morphology and cranial and/or climatic variables. If this is the case, the data should prove too random and high in variation to exhibit statistically significant differences from group to group. If this hypothesis is rejected, further testing will refine the relationship of frontal sinus morphology with craniometrics and climate data.

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Previous Research

Past investigations of the frontal sinuses have yielded information which fits into several contexts. Within the realm of human variation, Szilvassy, et al. state that: "...by utilizing metric and morphologic characteristics of the paranasal sinuses it is possible to recognize and differentiate the three main races of man (Europids, Mongolid and Negrid)" (1987: 1). Statistically significant interracial frontal sinus differences have been noted by Strek, et al. (1992) between Mongolian, Eskimo, Indian, and Cracovian samples. Hylander (1977: 135) notes that Koertvelyessy's 1972 study "...suggests that the more northerly [Alaskan Eskimo skeletal] populations are characterized by a smaller frontal sinus." Hanson and Owsley (1980) found that Canadian Eskimo from the regions surrounding Hudson Bay have smaller sinus areas than those reported for Alaskan Eskimo and Grand Quivera Pueblo, Arikara, and Zuni Indians.

Paleontological study of frontal sinus pattern has been limited relative to other anatomical features, but these studies do provide some information. A study of the frontal sinuses by Tillier finds that "...constant pneumatisation of the supraorbital torus is a characteristic feature of western European Neanderthal men and their predecessor of

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the Riss-Wurm interglacial whose Neanderthal affinities have been demonstrated" (1977: 1). Szilvassy, Kritscer and Vlcek find that "...the characteristics of the Neanderthal sinuses are within the range of variation of modern *Homo sapiens*, and especially resemble the European pattern" (1987: 346). Stringer, Hublin and Vandermeersch state that European Neanderthals have a frontal sinus that "...extends laterally, not superiorly" (1984: 55). Frayer states that, based on Stringer's observation, "...this [frontal sinus] morphology would appear to constitute a significant difference from more recent *Homo sapien*s" (1992: 27). Trinkaus used the frontal sinus dimensions of Fontechevade I as an indicator of age, stating that "...the interorbital breadth and frontal squamous thickness of Fontechevade I suggest juvenile status, while the size of the frontal sinus indicates a slightly older individual" (1973: 34).

Finally, Reichs (1993) shows that the frontal sinus provides for excellent forensic identification if perimortem CT or radiographs are available on the subject in question.

Despite the investigations mentioned above, controversy still surrounds the evaluation of frontal sinus form and function. This can be attributed to four factors. First, frontal sinuses are closed to direct observation without either the specimen being broken when found or deliberate invasion (either destructive or non-destructive) by the

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researcher. Second, the frontal sinus communicates with the middle meatus by way of the frontal recess, a narrow hour-glass shaped cleft (Shankar, et al, 1994). This lends the structure particularly vulnerable to pathology associated with blockage and/or exposure to infection and resulting remodeling, which in turn complicates morphologic study. Third, until relatively recently, the availability of technology to observe these spaces has been limited and expensive. Finally, the function of the frontal sinus is still poorly understood, which compounds the difficulty in developing a salient theory explaining variation in morphology.

Several of the studies cited above either directly or indirectly link sinus size and/or morphology with climatic or geographic data. However, none so far have provided a comprehensive synthesis of climatic, geographic, and populational data to explore this apparent connection. Through the use of radiographs, I will attempt to correlate frontal sinus morphology with cranial, geographic, and environmental variables.

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CHAPTER 2

MATERIALS AND METHODS

Samples

In order to assemble a sample which would represent the largest variation in climate types and provide an adequate sample size, human crania from a total of six localities were utilized. All the material used is housed at the Field Museum of Natural History in Chicago. Only relatively complete crania were included in order to facilitate a complete data set for craniometric assessment. To insure statistically sound sample sizes and elimination of variation caused by gender, individuals observations were limited to adult males over the age of twenty years. Sex of the crania was determined by both the observer and by reference of the original sample descriptions as recorded by Lyle Konnigsberg in 1986. The samples utilized in this analysis originated from; the Sumerian city state of Kish in modern Iraq, Baghdad in Iraq, unspecified localites in Egypt, Papua New Guinea, the Philippine Islands, and pre-contact Marqeuz Peru.

The above localities were chosen for two reasons. The emphasis on climate in this study requires a sample of populations which ideally represent extremes in climate classification. Following the Koppen-Geiger System of

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climate classification (Strahler and Strahler, 1984), a search for samples which represent such diversity and provide adequate sample size was initiated. Owing to logistical concerns and because both an extensive collection of crania and a facility for mass radiography were available at the Field Museum, I chose to restrict data collection to the remains housed there.

Six samples were found which represent two climate types. A tropical rainforest climate is represented by samples from Melanesia and the Philippines. A tropical rainforest is characterized by its coolest month not falling below 18 degrees Celsius with precipitation present through the entire year (Strahler and Strahler, 1984). A tropical and subtropical desert is represented by samples from Iraq, Egypt, Kish, and Marquez, Peru. A tropical desert is characterized by mean annual temperature over 18 degrees Celsius, all months with a temperature above 0 degrees Celsius and a dry season in winter (Strahler and Strahler, 1984). This combination of climate type is not ideal in that it does not reflect the full range of climate to which humans are adapted. On the other hand, the areas from which the sample come do represent signficant variation in both temperature and precipitation averages and variability and thus allow for a limited testing of the null hypothesis.

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All sample information was drawn from catalog records and original excavation notes housed at Field Museum's Department of Anthropology.

Melanesia

The Melanesian collection housed at Field Museum consists of well preserved individuals of both sexes and varying age. After sorting for sex and age, a data sample was established which consisted of 21 individuals from the Gazelle Peninsula on the island of New Britain, seven from the island of Warapu, and two from the island of Borbor, for a total number of 30 individuals in this sample. Individuals within this sample were either collected in the 1913 Joseph N. Field Expedition or were bought from R. Parkinson in 1898. All individuals are without archaeological context. All crania are complete with no sign of pathology.

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Philippines

The Philippine collection is also well preserved, though individuals were somewhat more damaged. A total of 19 crania were used and came from the R.J. Cummings Expedition of 1907, purchased, or obtained through a donation. Localities represented are; the Boulic Provence on Sagada, North Luzon, Upper Cagayau River on Luzon, Baname in North Central Luzon, Mayayao in North Central Luzon, South Muidoro, and Bohol Island. All individuals are without archaeological context. No pathology was observed on any of the specimens.

Peru

The Peruvian sample derives from the Captain Marshall Field Archaeological Expedition of 1925 in the Lower Chillon Valley of Peru. The sample comes from Cemetary “A” in Marquez and is dated from 900 A.D. to 1500 A.D. representing a pre-contact population. The sample yielded 14 individuals of the appropriate and sex. Cradle “boarding” is present on all individuals within the sample and as such, no craniometrics were performed on this sample. Only one individual in this sample exhibited any gross pathology which consisted of periosteal lesions on the parietals.

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Iraq

The Iraqi represent a modern cemetary population from the city of Baghdad. The sample was collected during the Field Museum Near East Expedition of 1934. A total of eight crania were surveyed and none exhibit any major pathological conditions. All crania are complete with minimal breakage.

Egypt

The Egyptian sample consists of three crania. None exhibited congenital or gross pathological conditions. All specimens in the sample are complete. Dating is not known as all were obtained through donation. In addition, only one has any geographic context which is described as “the tombs near the Sahara pyramid near Cairo.”

Kish

The Kish sample was drawn from a collection dated from 2800 B.C. to 539 B.C. (Rathbun, 1984). Samples represent a cemetary population and were collected between 1923 through 1934 during the Field Museum-Oxford Joint Expedition. The sample consists of 10 individuals. Individuals were chosen on the basis of preservation and lack of pathology.

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Data

Although the focus of this project is the frontal sinus, it is important to view this feature in its proper context. For this reason, radiographs of the frontal sinus, traditional craniometric measurements, and climate data were collected.

Frontal Sinus Morphology

The development of the frontal sinus is the result of two simultaneous processes, the progressive advancement of the sinus mucosa and concomitant resorption of the overlying bone (Shapiro and Janzen, 1960). The frontal sinus extends superiorly into the superciliary region and then posteriorly above the roof of the orbit (Shankar, et al., 1994). In addition, the frontal sinus may extend into the crista galli (Shapiro and Janzen, 1960). The interior wall of the frontal sinus is lined with mucous membrane and the mucoperiosteal border appears as a sharply defined white line in radiographs (Shapiro and Janzen, 1960). The frontal sinuses are normally asymmetrically separated by a bony septum and connected to the middle meatus via the frontal recess which allows secretions to drain (Shankar, et al., 1994). This results from an often irregular resorption of the diplo in the vertical portion of the frontal bone (Shapiro and Janzen, 1960).

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Undeveloped at birth, the frontal sinus appears in the second year as a result of the pneumatization of the anterior portion of the frontal recess or from an anterior ethmoidal cell (Shankar, et al., 1994). By the middle of the third year, the cupola of the sinus appears above the level of nasion (Shapiro and Janzen, 1960). By eight years of age the superior border extends to the height of the supraorbital rim. By ten years of age, it may reach superiorly into the supercilliary region (Shankar, et al., 1994).

Once developed, the frontal sinus is subject to a wide range of pathological modifications. These include: enlargement due to the thinning of frontal sinus walls which is in turn due to old age; post-menopausal symmetrical hyperostosis on the inner surface of the forehead causing reduction; chronic inflammatory conditions (i.e., sinusitis) causing the thinning or thickening of the compact lamina and subsequent enlargement or reduction of the frontal sinus; injuries, tumors, and obstruction of the fronto-nasal duct causing frontal sinus enlargement (Schuller 1943).

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Frontal Sinus Data Collection

Frontal sinus data were obtained by filming an anterior-posterior view of each individual on DuPont 10T medical radiograph film. Each cranium was placed in a Styrofoam support and aligned into the Frankfort Horizontal relative to the film plane using a plumb bob. A one-centimeter rod of steel was affixed at approximately nasion to provide reference for scaling the inherent magnification of the image. The emitter-to-film distance was kept at 40 inches and exposure time was 1.25 minutes at 90 kv/ 5 ma. The exposure serial number was recorded on the film using radiograph opaque numbers. These numbers were then added to the appropriate Field Museum catalog number entry in the study records.

The radiographic images were then scanned into the Canvas technical illustration program running on an IBM-compatible PC. This facilitated the accurate measurement of the frontal sinus through image magnification, high tolerance tracing via a drawing tablet, and the Canvas measurement utility, which provides height, width, area and perimeter calculation for irregularly shaped objects. Once scanned, the image was magnified to 400%. The magnification reference, the steel rod, was located and traced. To facilitate consistency, the frontal sinuses were traced beginning with the left-most lateral projection and proceeded clockwise. Because of difficulty delimiting the

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inferior border of the frontal sinus, previous researchers have often drawn a baseline tangential to the superior borders of the orbit (Libersa and Faber, 1953; Brothwell et al., 1968; Koertvelyessy, 1972; Hanson and Owsley, 1980; Francis et al., 1990). This procedure, though appropriately conservative, will often drastically decrease the estimated measurements if not eliminating recognition of a frontal sinus altogether (see Figure 1).

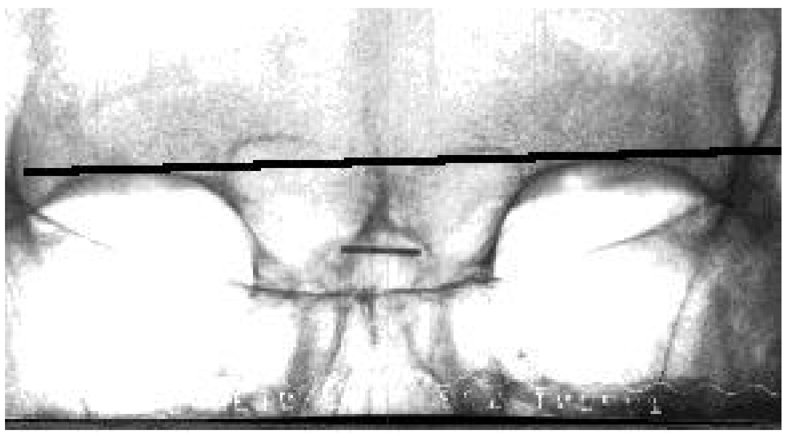

Figure 1. Showing tangential line drawn across the superior margin of the orbits and the resulting exclusion of potential sinus information.

Two-dimensional sinus data was chosen for evaluation. Three-dimensional analysis is ideally suited for such a feature as it would provide a much more realistic representation of the true morphologic nature of the frontal sinuses. Sinuses could then be measured and compared by their true volume and interior surface area. However, the cost of obtaining such data coupled with the increased

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complexity in processing it preclude its use in this study. Although two-dimensional data does not provide true representation of volumetric morphology, its efficiency does allow comparisons of overall morphology across a large sample.

Utilizing the magnification capabilities of Canvas, the sinuses were traced and the data computed (see Figure 2). Due to the imaging quality and the magnification allowed by Canvas, I did not feel that the exclusion of any sinus structure below the superior margin of the orbits was warranted. Instead, when confusion was encountered in the identification of the inferior border of the frontal sinus, the most anatomically conservative trace was utilized. Frontal sinus metrics were measured and recorded in this manner. Each measurement was matched with its corresponding value for magnification error (recorded as Length in Figure 2) and adjusted accordingly.

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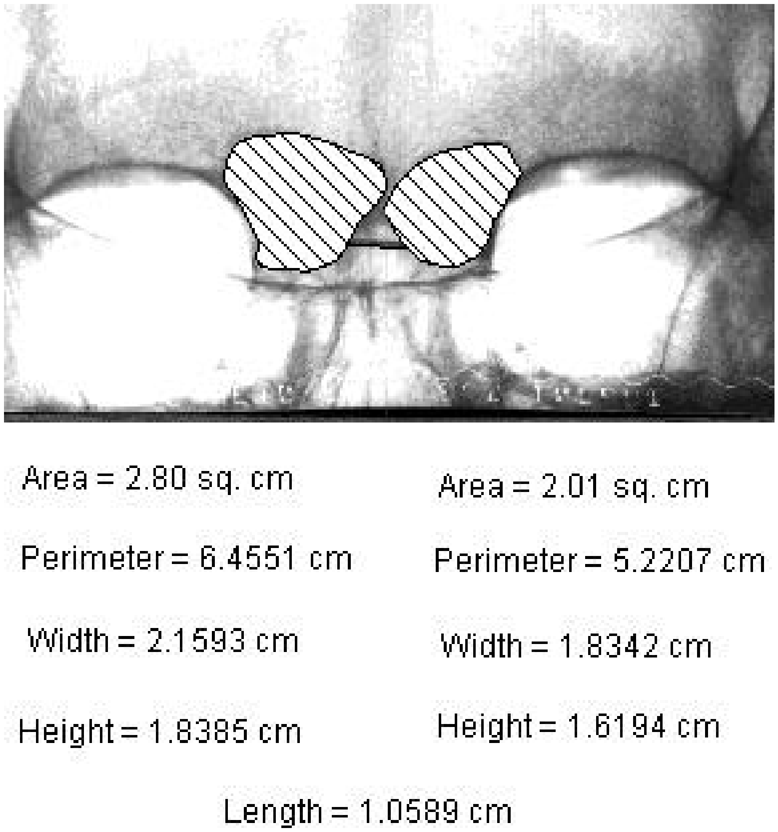

Figure 2. Tracing of the frontal sinus and calculations of sinus dimensions.

Table 3 lists the frontal sinus variables used. All values were originally measured in centimeters and then converted to millimeters before statistical analysis. In most cases the division between the left and right sinus was clear. When multiple divisions created a middle structure, a value was recorded distinct from left and right values. Canvas allows the accurate calculation of irregularly shaped objects; thus, area measurements are accurate in regard to edge complexity, not simply a function of height times width. Area measurements reflect the general size of the frontal sinus cavity in square millimeters. Perimeter

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measurements reflect complexity of frontal sinus form. A frontal sinus with greater degrees of convolutions will have a greater perimeter than one with less convolutions, much like a radiator in an automobile. Height and width measurements reflect the extension of the frontal sinus into the frontal bone.

Table 3. Frontal Sinus Metrics.

	Abbreviation	Description
1.	LAREA	Left Area (mm^2)
2.	MAREA	Middle Area (mm^2) when present
3.	RAREA	Right Area (mm^2)
4.	TOTAREA	Total Area (mm^2)
5.	LPERIM	Left Perimeter (mm)
6.	MPERIM	Middle Perimeter (mm) when present
7.	RPERIM	Right Perimeter (mm)
8.	LWIDTH	Left Width (mm)
9.	MWIDTH	Middle Width (mm) when present
10.	RWIDTH	Right Width (mm)
11.	LHGHT	Left Height (mm)
12.	MHGHT	Middle Height (mm) when present
13.	RHGHT	Right Height

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Craniometrics

Traditional craniometrics were chosen to extract maximum distance as discussed by Wright (1992) in developing the CRANID cranial identification program. These measurements are drawn from and follow Howells (1973) (see Table 4). Wright used 2,524 crania measured by Howells (1973; 1989) to develop an algorithm which reduces “the uncertainty of determining the origins of a person’s ancestors in terms of the ethnographic present” on a world-wide scale (Wright, 1992: 129). In addition, these algorithms are argued to be of value in assessing the biologic affinity of prehistoric specimens (Wright, 1992).

Linear measurements were taken with needle-nose or spreading Mitutoyu calipers where appropriate. Subtense measurements were taken with coordinate calipers. Because of the large number of individuals in the sample and the large number of variables in the study, only one measurement was taken for each variable.

In addition to these variables, three ratios were calculated. Nasal Shape (NRATIO) represents the shape of the nasal aperature and is calculated by dividing Nasal Height (NLH) by Nasal Breadth (NLB). Cranial Shape (SHAPE) represents the shape of the crania in the transverse plane

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Table 4. Craniometrics.

	Abbreviation	Description
1.	GOL	Glabello-Occipital Length
2.	NOL	Nasio-Occipital Length
3.	BNL	Basion-Nasion Length
4.	BBH	Basion-Bregma Height
5.	XCB	Maximum Cranial Breadth
6.	XFB	Maximum Frontal Breadth
7.	AUB	Biauricular Breadth
8.	ASB	Biasterionic Breadth
9.	BPL	Basion-Prosthion Length
10.	NPH	Nasion-Prosthion Height
11.	NLH	Nasal Height
12.	OBH	Orbital Height, Left
13.	OBB	Orbital Breadth, Left
14.	JUB	Bijugal Breadth
15.	NLB	Nasal Breadth
16.	MAB	Palate Breadth, External
17.	ZMB	Bimaxillary Breadth
18.	SSS	Zygomaxillary Subtense
19.	FMB	Bifrontal Breadth
20.	NAS	Nasio-Frontal Subtense
21.	EKB	Biorbital Breadth
22.	DKB	Interorbital Breadth
23.	WMH	Cheek Height
24.	FRC	Frontal Chord
25.	FRS	Frontal Subtense
26.	PAC	Parietal Chord
27.	PAS	Parietal Subtense
28.	OCC	Occipital Chord
29.	OCS	Occipital Subtense
30.	NRATIO	Nasal Shape (NLH / NLB)
31.	SHAPE	Transverse Cranial Shape (GOL/XCB)
32.	BROW	Sagital Supracilliary Protrusion (GOL-NOL).

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at its greatest breadth and length. Sagital Supracilliary Protrusion (BROW), Glabello-Occipital Length minus Nasio-Occipital Length, represents the extension of glabella forward of nasion in the mid-sagital plane.

Climate Data

Climate data was drawn from the National Oceanographic and Atmospheric Administration National Climatic Data Center’s Global Daily Summary Compact Disc database. This database is designed for use on an IBM-compatible PC and allows the sorting and extraction of daily weather summaries for over 10,000 stations world-wide.

This database allows transcendence of generalizations when coding climate by allowing quantitative rather than qualitative assessment of weather. Daily values of maximum and minimum temperature allow flexibility in analysis by providing raw values. These values can then be used to track seasonal trends, inter-seasonal and intra-seasonal variability, and a variety of indices such as Median Daily Temperature, Average Yearly Temperature, etc. Daily Precipitation values function in the same way. Variables chosen for this study are listed in Table 5.

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Table 5. Climate Variables

MAXTMP	Maximum Daily Temperature Centigrade
MINTMP	Minimum Daily Temperature Centigrade
AVGTMP	Median Daily Temperature (MAXTMP+MINTMP / 2) Centigrade
PRECIP	Daily Precipitation (Millimeteres)

Station localities (Table 6) were chosen to facilitate relative geographic proximity to the location from which the appropriate skeletal samples in were drawn. When the sample consisted of individuals from a wide range of localities, or from unknown localities, stations were chosen which represent the region as a whole.

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Table 6. Station Localities

Egypt

STN	Locality	LAT	LON	ELEV
62300	SALLOUM	3153	33482	4
62306	MERSA MATRUH	3132	33278	28
62318	ALEXANDRIA/NOUZHA	3120	33005	7
62333	PORT SAID/EL GAMEEL	3128	32777	6
62366	CAIRO	3013	32860	74
62387	MINYA	2808	32927	39
62432	DAKHLA	2548	33100	106
62465	KOSSEIR	2613	32570	11

Iraq

STN	Locality	LAT	LON	ELEV
40602	RABIAH	3680	31790	382
40604	SINJAR	3632	31817	476
40605	ZAKHO	3713	31732	442
40621	KIRKUK	3547	31560	331
40634	HADITHA	3407	31763	172
40650	BAGHDAD	3323	31577	34
40676	NASIRIYA	3108	31377	3
40689	BASRAH	3057	31222	2

Papua New Guinea (Melanesia)

STN	Locality	LAT	LON	ELEV
94004	WEWAK	-357	21637	5
94014	MADANG	-522	21420	12
94035	PORT MORESBY	-943	21278	28
94044	MOMOTE	-207	21257	4
94085	RABAUL	-422	20782	5
94087	MISIMA	-1070	20717	17

(Continued on next page)

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Table 6. Station Localities (Continued).

Peru

STN	Locality	LAT	LON	ELEV
84452	CHICLAYO	-678	7983	31
84472	CAJAMARCA	-713	7847	2620
84531	CHIMBOTE	-917	7852	20
84542	HUARAZ	-935	7760	2750
84628	LIMA-CALLAO/CHAVEZ	-1200	7712	13
84691	PISCO	-1375	7622	6

Philippines

STN	Locality	LAT	LON	ELEV
98133	CALAYAN	1927	23853	12
98135	BASCO, BATAN ISLAND	2045	23803	10
98223	LAOAG, LUZON	1818	23947	4
98426	CUBI POINT, LUZON	1480	23973	17
98429	MANILA AIRPORT, LUZON	1452	23900	23
98548	CATBALOGAN, SAMAR	1178	23512	3
98644	TAGBILARAN, NEGROS	963	23613	5
98753	DAVAO AIRPORT	712	23435	25

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Statistical Analysis

The statistical analysis proceeded in two phases. During Phase One, the assumption of normality was tested. If the samples were found to be normally distributed, the most robust parametric statistical procedures could be used. If a non-normal distribution was found, less robust, but still valid, non-parametric testing would be carried out. Conclusions based on these procedures are secure in both assumptions and validity. Phase One continued with a difference of means tests to establish whether the frontal sinus size of individuals from a particular sample differed from the mean frontal sinus size of the other samples. This step is vital in establishing that differences do exist. Without such differences, no further analysis is required.

Phase Two consisted of a number of sub-phases which were designed test to hypotheses which emerged from the results of Phase One. These included tests for correlation between sinus size, craniometrics, and climate data. The first goal was to see to what extent allometric scaling affects the difference in sinus size between samples. Principal Components Analysis reduces a large set of variables into a series of orthogonal components which represent distinct variability among groups. Often, the first Principal Component represents that portion of total variability which is accounted for in size (Manly, 1986).

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For this reason, a Principal Components Analysis was used to test the presence and impact of allometric scaling.

The second goal was to see if any individual variables are significantly correlated with frontal sinus size. In order to test this, an Analysis of Variance was conducted. Variables which appeared to differentiate the samples in the same manner as the frontal sinuses were then used in a correlation analysis to test their relationship to the frontal sinus.

The third goal was to see if any combination of cranial variables would sufficiently account for the variation seen in the frontal sinus. To accomplish this a search for a multiple regression which maximizes adjusted r^2 was performed. Because the addition of any variable, no matter how uncorrelated, automatically increases r^2, it is important to maximize adjusted r^2 when conducting a search in multivariate regression (Bowerman and O'Connell, 1990).

Finally, climate data were considered as a potentially contributing factor in frontal sinus size. When plotted, the data reveal a regular differential pattern between the sample areas. These patterns were standardized into coefficicients of variation which then were used in a correlation analysis with frontal sinus size variables.

All tests proceeded using two data subsets where applicable, one that counts an absence of sinus data as a

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missing value, and one that counts those observations as a zero value. Because the frontal sinus can be radiographically opaque if filled with matrix, the calculation of test statistics using both data subsets with missing observations and those with zero values in place of a missing value allows the certainty of non-biased interpretation. Only when the absence of frontal sinus morphology is recorded as zero do the subsequent tests reflect a true absence of the sinus. Observations which contain variables with missing values are deleted from test procedures by the SAS software (SAS, 1994) requiring the data design to include both types of data sets.

All statistical processes in this project were conducted utilizing the SAS/STAT System running in the Windows environment on an IBM-compatible PC. Databases were constructed using Microsoft Works Spreadsheet, then converted to the text-based SAS dataset format before processing.

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CHAPTER 3

RESULTS

Phase One

Univariate Testing

In order to conduct a statistically valid test of all hypotheses, the data were first subjected to univariate procedure to assess the assumption that the data are normally distributed. This facilitated the choice of parametric or non-parametric procedures to be conducted in subsequent tests. The initial test for normality was limited to only the frontal sinus variables. Tests of normality conducted on middle frontal sinus variables are not included in Tables 7 and 8. All middle frontal sinus samples tested normal if sample size was sufficient for such a test to be carried out.

Table 7 details the results of the test for normality on the dataset which included missing values. Five cases of non-normal distributions were found. These are; Kish (LAREA and RAREA), Egypt (RAREA and RPERIM), and the Philippine (TOTPERIM).

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Table 7. Frontal Sinus Variable Normality Tests for Missing Value Data Subset

Variable	Sample	#OBS	Score	Mean(mm)	Normal	Non-Normal
LAREA	EGYPT	3	.2662	56.25	X	
	IRAQ	8	.1895	48.75	X	
	KISH	8	.0346	31.54		X
	MEL	25	.4148	24.83	X	
	PERU	14	.8961	26.01	X	
	PHIL	17	.1539	35.15	X	
RAREA	EGYPT	3	.1864	46.90		X
	IRAQ	8	.2226	66.61	X	
	KISH	9	.0158	25.45		X
	MEL	25	.7319	33.26	X	
	PERU	14	.4347	23.91	X	
	PHIL	17	.9658	39.71	X	
TOTAREA	EGYPT	3	.3409	103.15	X	
	IRAQ	8	.6867	117.52	X	
	KISH	9	.2250	51.50	X	
	MEL	25	.6742	62.37	X	
	PERU	14	.2412	50.97	X	
	PHIL	17	.1132	74.86	X	
LPERIM	EGYPT	3	.1559	105.37	X	
	IRAQ	8	.6474	91.32	X	
	KISH	8	.0261	64.32	X	
	MEL	25	.5027	62.49	X	
	PERU	14	.9780	63.81	X	
	PHIL	17	.1875	77.01	X	
RPERIM	EGYPT	3	.0235	81.12		X
	IRAQ	8	.4768	101.01	X	
	KISH	9	.0872	58.10	X	
	MEL	25	.4092	67.31	X	
	PERU	14	.4739	56.32	X	
	PHIL	17	.2462	76.64	X	
TOTPERIM	EGYPT	3	.4318	186.49	X	
	IRAQ	8	.9012	199.39	X	
	KISH	9	.7613	119.70	X	
	MEL	25	.1030	139.65	X	
	PERU	14	.2499	124.14	X	
	PHIL	17	.0103	153.65		X

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Table 8 details the results of the test for normality on the dataset which substitutes zero values in place of missing values. Five cases of non-normal distributions were found. These are; the Philippines (LPERIM, RPERIM, TOTPERIM), Egypt (RPERIM), and Melanesia (RPERIM).

Difference of Means Testing

A difference of means test was conducted on all sinus variables with the samples grouped into geographic affinity. The PROC GLM procedure was used to conduct the ANOVA procedure as it is better suited to handle unbalanced data than the PROC ANOVA procedure (SAS, 1994). Student's t-test statistic was used in cases where the data met the assumption of normality. The non-parametric Wilcoxon t-test approximation was used in cases where the assumption of normality was not met.

Table 9 and 10 detail the results of these tests. All test were conducted at the alpha=.05 level. The null hypothesis for these tests is that no difference in means exists. Parametric tests which rejected the null hypothesis are noted with an asterisk. Non-parametric tests which rejected the null hypothesis are noted with a plus sign.

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Table 8. Frontal Sinus Variable Normality Tests for Zero Value Data Subset.

Variable	Sample	#OBS	Score	Mean(mm)	Normal	Non-Normal
LAREA	EGYPT	3	.2661	56.25	X	
	IRAQ	8	.1895	48.75	X	
	KISH	10	.1216	25.24	X	
	MEL	30	.0724	20.69	X	
	PERU	14	.8961	26.01	X	
	PHIL	19	.6678	31.45	X	
RAREA	EGYPT	3	.1864	46.90	X	
	IRAQ	8	.2226	66.61	X	
	KISH	10	.0931	20.36	X	
	MEL	30	.1613	27.72	X	
	PERU	14	.4347	23.91	X	
	PHIL	19	.9322	35.53	X	
TOTAREA	EGYPT	3	.3409	103.15	X	
	IRAQ	8	.6867	117.52	X	
	KISH	10	.3542	46.35	X	
	MEL	30	.3388	51.97	X	
	PERU	14	.2412	50.97	X	
	PHIL	19	.3252	66.98	X	
LPERIM	EGYPT	3	.1559	105.37	X	
	IRAQ	8	.6474	91.32	X	
	KISH	10	.3688	45.03	X	
	MEL	30	.0682	52.07	X	
	PERU	14	.9780	63.81	X	
	PHIL	19	.0019	68.91		X
RPERIM	EGYPT	3	.0235	81.12		X
	IRAQ	8	.4768	101.01	X	
	KISH	10	.6088	46.47	X	
	MEL	30	.0223	56.09		X
	PERU	14	.4739	56.32	X	
	PHIL	19	.0422	68.57		X
TOTPERIM	EGYPT	3	.4318	186.49	X	
	IRAQ	8	.9012	199.39	X	
	KISH	10	.7466	95.76	X	
	MEL	30	.0578	116.38	X	
	PERU	14	.2499	124.14	X	
	PHIL	19	.0012	137.48		X

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Table 9. Frontal Sinus Variable Difference of Means Test Missing Value Data Subset.

---

* = Statistically significant at alpha = .05 parametric
\+ = Statistically significant at alpha = .05 non-parametric

<u>LAREA</u>

	EGYPT	IRAQ	KISH	MEL	PERU	PHIL
EGYPT	-			*	*	*
IRAQ	-	-		*	*	*
KISH	-	-	-			
MEL	-	-	-	-		*
PERU	-	-	-	-	-	
PHIL	-	-	-	-	-	-

<u>RAREA</u>

	EGYPT	IRAQ	KISH	MEL	PERU	PHIL
EGYPT	-				*	
IRAQ	-	-	+	*	*	*
KISH	-	-	-			
MEL	-	-	-	-		
PERU	-	-	-	-	-	*
PHIL	-	-	-	-	-	-

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Table 9 Continued. Frontal Sinus Variable Difference of Means Test Missing Value Dataset

<u>TOTAREA</u>

	EGYPT	IRAQ	KISH	MEL	PERU	PHIL
EGYPT	--------		*	*	*	
IRAQ	--------	--------	*	*	*	*
KISH	--------	--------	--------			*
MEL	--------	--------	--------	--------		
PERU	--------	--------	--------	--------	--------	*
PHIL	--------	--------	--------	--------	--------	--------

<u>LPERIM</u>

	EGYPT	IRAQ	KISH	MEL	PERU	PHIL
EGYPT	--------			*	*	*
IRAQ	--------	--------		*	*	
KISH	--------	--------	--------			
MEL	--------	--------	--------	--------		*
PERU	--------	--------	--------	--------	--------	
PHIL	--------	--------	--------	--------	--------	--------

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Table 9 Continued. Frontal Sinus Variable Difference of Means Test Missing Value Dataset

RPERIM

	EGYPT	IRAQ	KISH	MEL	PERU	PHIL
EGYPT	--------					
IRAQ	--------	--------	*	*	*	*
KISH	--------	--------	--------			*
MEL	--------	--------	--------	--------		
PERU	--------	--------	--------	--------	--------	*
PHIL	--------	--------	--------	--------	--------	--------

TOTPERIM

	EGYPT	IRAQ	KISH	MEL	PERU	PHIL
EGYPT	--------		*		*	+
IRAQ	--------	--------	*	*	*	+
KISH	--------	--------	--------			
MEL	--------	--------	--------	--------		
PERU	--------	--------	--------	--------	--------	+
PHIL	--------	--------	--------	--------	--------	--------

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Table 10. Frontal Sinus Variable Difference of Means Test Zero Value Data Subset.

---

* = Statistically significant at alpha = .05 parametric
+ = Statistically significant at alpha = .05 non-parametric

<u>LAREA</u>

	EGYPT	IRAQ	KISH	MEL	PERU	PHIL
EGYPT	--------		*	*	*	*
IRAQ	--------	-------	*	*	*	*
KISH	--------	-------	-------			
MEL	--------	-------	-------	-------		*
PERU	--------	-------	-------	-------	-------	
PHIL	--------	-------	-------	-------	-------	-------

<u>RAREA</u>

	EGYPT	IRAQ	KISH	MEL	PERU	PHIL
EGYPT	--------		*			
IRAQ	--------	-------	*	*	*	*
KISH	--------	-------	-------			*
MEL	--------	-------	-------	-------		
PERU	--------	-------	-------	-------	-------	
PHIL	--------	-------	-------	-------	-------	-------

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Table 10 Continued. Frontal Sinus Variable Difference of Means Test Zero Value Data Subset.

TOTAREA

	EGYPT	IRAQ	KISH	MEL	PERU	PHIL
EGYPT	--------		*	*	*	
IRAQ	--------	-------	*	*	*	*
KISH	--------	-------	-------			
MEL	--------	-------	-------	-------		
PERU	--------	-------	-------	-------	-------	
PHIL	--------	-------	-------	-------	-------	-------

LPERIM

	EGYPT	IRAQ	KISH	MEL	PERU	PHIL
EGYPT	--------		*	*	*	
IRAQ	--------	-------	*	*	*	
KISH	--------	-------	-------			
MEL	--------	-------	-------	-------		
PERU	--------	-------	-------	-------	-------	
PHIL	--------	-------	-------	-------	-------	-------

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Table 10 Continued. Frontal Sinus Variable Difference of Means Test Zero Value Data Subset.

<u>RPERIM</u>

	EGYPT	IRAQ	KISH	MEL	PERU	PHIL
EGYPT	--------					
IRAQ	--------	--------	*	*	*	+
KISH	--------	--------	--------			
MEL	--------	--------	--------	--------		
PERU	--------	--------	--------	--------	--------	
PHIL	--------	--------	--------	--------	--------	--------

<u>TOTPERIM</u>

	EGYPT	IRAQ	KISH	MEL	PERU	PHIL
EGYPT	--------		*	*		+
IRAQ	--------	--------	*	*	*	+
KISH	--------	--------	--------			
MEL	--------	--------	--------	--------		
PERU	--------	--------	--------	--------	--------	
PHIL	--------	--------	--------	--------	--------	--------

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Discussion

The first important hypothesis to test is whether any of the total frontal sinus area means (TOTAREA) are different between groups. The associated data--left and right area and left and right perimeter--will be used to increase the precision of the initial finding later in the study. Tables 9 and 10 clearly indicate that a difference exists in the total frontal sinus size between the samples.

More precisely, a consistent pattern emerges in both subsets of data, those which exclude missing values and those which treat those missing values as zero. Individuals in the Iraqi sample (117.52 mm^2) possess statistically significantly larger total sinus area (TOTAREA) than the Kish (53.72 mm^2), Melanesian (62.37 mm^2), Peruvian (50.97 mm^2), and Philippine samples (74.86 mm^2), but are not statistically distinct from the Egyptian sample (103.15 mm^2). This is also the case when comparing the Egyptian sample, which has statistically distict sinus size when compared with the Kish, Melanesian, and Peruvian samples. Only the Philippine sample fails to test statistically distinct from the Egyptian. This is most likely due to the one severe outlying observation in the Philippine sample, which has a total sinus area of 145.65 mm^2 (the next highest observation is 112.35^2 mm) coupled with the smaller, but not

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significantly different Egyptian mean as compared to the Iraqi sample.

What is very suprising, however, is that the Kish sample falls out with the Melanesian, Peruvian, and Philippine samples in total frontal sinus area, but not with the Iraqi sample. Further, the disparity between the Kish and Iraqi samples is second greatest among all the samples. The Iraqi mean total area of 117.52 mm^2 is more than twice the Kish value of 53.72 mm^2.

Finally, in the subset of data which excludes missing sinus data, the Peruvian total sinus area mean (TOTAREA) of 50.97 mm^2 is statistically smaller than the Philippine mean (TOTAREA) of 74.86 mm^2. This again may be due to the severe outliner contained in the Philippine data set, but in the end should not be ignored.

When the data are examined in more detail, additional patterns emerge. When missing values are dropped, the Iraqi right frontal sinus area mean (RAREA) is statistically larger than the Kish, Melanesian, Peruvian, and Philippine samples. The left frontal sinus area mean (LAREA) does not statistically differ between the Iraqi and Kish samples. Since total frontal sinus area mean (TOTAREA) between Iraq and Kish tests significantly different, but only right frontal sinus area mean (RAREA) shows significance when tested separately, the difference in TOTAREA between Iraq

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and Kish can be attributed to the RAREA disparity between groups. When missing values are counted as zero, the Iraqi left and right frontal sinus area means (LAREA & RAREA) test different from all other samples except the Egyptian.

Egyptian TOTAREA is statistically distinct from the Kish, Melanesian, and Peruvian samples, but not from the Iraqi nor the Philippine samples, in both missing value and zero value runs. Again, the extreme outliner contained in the Philippine sample may partially influence this result.

Total frontal sinus perimeter mean (TOTPERIM) follows the same type of pattern as TOTAREA. Iraqi TOTPERIM is significantly larger than from all other samples, except Egypt, when missing values are dropped and when missing values are counted as zero.

Iraqi RPERIM tests as significantly larger than all other samples except Egypt in both missing value and zero value runs. LPERIM shows significantly larger values between Iraq versus the Melanesian and Peruvian in the missing value run and the Kish, Melanesian, and Peruvian during the zero value run. The same pattern seen in LAREA and RAREA between the Iraqi sample and the Kish sample emerges in LPERIM and RPERIM. When missing values are dropped, only RPERIM is statistically distict between Iraq and Kish. When missing values are counted as zero, both LPERIM and RPERIM test as statitically different.

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Phase One was designed to test whether the aggregate frontal sinus variables, TOTAREA and TOTPERIM, differed among groups. The blanket null hypothesis for this phase of testing is:

Ho: No statistically significant difference in means exists between sample groups.

This null hypothesis was rejected and replaced with the alternate hypothesis:

Ha: The difference in the sample means are statistically significant.

Specifically, we see a general congregation of non-statistically different frontal sinus traits in the Kish, Melanesian, Peruvian, and Philippine samples. In addition, we see that all groups consistently test as statistically different from the Iraqi sample with one exception, the Egyptian sample.

In summary, the data show that the Iraqi and Egyptian samples possess statistically larger frontal sinuses than the Kish, Melanesian, Peruvian, and Philippine samples. In addition, the data suggest that the Melanesian and Philippine samples do not differ in frontal sinus size or asymmetry. Further, the Kish and Peruvian samples test as

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somewhat smaller than the upper extreme of this group, the Philippine sample.

Phase Two

The object of Phase Two was to systematically test various hypotheses that may account for the results gained in Phase One. With the establishment that a real difference does exist in frontal sinus size between groups, a stochastic explanation becomes improbable.

To search for a non-stochastic explanation, the study proceeded in a stepwise fashion. The first, and most obvious variant that might account for the difference in sinus size, is allometric scaling. This was investigated utilizing both univariate and multivariate techniques. Once allometric scaling was ruled out as a potential contributing factor in the disparate frontal sinus size witnesed among groups, a more detailed investigation began. The focus tightened and an attempt to correlate the frontal sinus size and craniometric data began. Finally, climate was introduced and tested as the possible contributing factor for disparate frontal sinus size.

Test One: Allometric Scaling

A robust method for analyzing the effect of allometric scaling when comparing any two given samples is the use of

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Principal Component Analysis. A Principal Component Analysis collapses a set of variables used into a series of linear functions which often represent a particular shared variability common to all observations (Manley, 1986). The Principal Components are ordered by their contribution in explaining total variablility. Since the first Principal Component accounts for the most variation relative to the other Principal Components, size is usually accounted for at this level (Manley, 1986). The percentage of the total variability accounted for by the Principal Component related to size gives insight on how much allometry might play a part in sample differentiation. In this case, if the Principal Component related to size is heavily weighted, allometry must be considered as a contributing factor in the disparity of frontal sinus size among the sample groups.

A Principal Component Analysis was run on the 29 cranial variables for all skeletal samples except the Peruvians, as no craniometrics were recorded for this group. The samples were lumped in an aggregate dataset in order to capture the variability between samples. If size is accounted for in any one Principal Component, a particularly high loading (eigenvector), approaching 1.0, should appear corresponding to some combination of variables that most reflect size. These would include; GOL, NOL, XCB, XFB, ASB, FRC, PAC, OCC. Table 11 lists the results of this analysis.

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The five greatest variable loadings in the first Principal Component are highlighted. The poor correlation of PC1 and the variables is immediately apparent.

The failure of this test to produce any high loadings (greater than .5) in any of the eigenvectors suggests that the Principal Component Analysis failed to bring into resolution isolated trends responsible for the variation (i.e. size). Further, this Principal Component Analysis failed to account for more than 90% of the variation until after the 15th PC had been added with the 1st Principal Component only accounting for 21.11% of the total variation in the dataset.

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Table 11. Principal Components Analysis of Craniometric Variables.

PC #	1	2	3	4	5
Eigenvalue	6.1219	3.7750	3.1045	2.0195	1.9316
Difference	2.3468	0.6705	1.0851	0.0878	0.2403
Proportion	0.2111	0.1302	0.1071	0.0696	0.0666
Cumulative	0.2111	0.3413	0.4483	0.5180	0.5846
GOL	**0.24354**	0.08798	0.39360	-0.05880	-0.08861
NOL	0.22865	0.11562	0.41182	-0.07284	-0.02970
BNL	0.21281	0.06342	0.21090	0.22687	0.19933
BBH	0.19303	0.25744	0.00351	0.20224	0.11498
XCB	0.03395	0.33027	-0.26980	-0.18613	0.06125
XFB	0.16098	0.34108	-0.14392	-0.07981	0.21297
AUB	**0.24722**	0.07563	-0.24230	-0.15850	-0.06390
ASB	0.22038	0.02045	-0.04930	-0.28627	-0.01228
BPL	0.16260	-0.29961	0.06024	0.27497	0.06911
NPH	0.15928	0.18202	0.07735	0.26940	-0.00040
NLH	**0.26297**	0.08759	-0.09811	0.09751	0.02016
OBH	0.09741	0.07127	-0.11566	-0.04239	0.22407
OBB	0.22905	-0.17908	-0.07486	0.01898	0.27436
JUB	**0.29189**	-0.11321	-0.16488	-0.24223	0.00518
NLB	0.12731	-0.22174	-0.08635	0.16358	-0.18846
MAB	0.18496	-0.06624	-0.11248	0.23232	-0.18092
ZMB	0.20316	-0.08967	-0.23563	0.06084	-0.10377
SSS	0.06320	-0.21429	0.02769	0.27300	0.18900
FMB	**0.31639**	-0.19041	-0.09264	-0.10664	0.07196
NAS	0.09621	-0.02654	0.25967	0.17932	0.32152
EKB	**0.31305**	-0.21731	-0.12724	-0.13618	0.00825
DKB	0.12749	-0.12293	-0.09624	-0.03775	-0.08000
WMH	0.10824	0.12025	0.02789	0.11316	-0.27335
FRC	0.11577	0.29113	0.01576	0.11341	0.14051
FRS	- 0.00546	0.33679	-0.10403	0.06339	0.18033
PAC	0.16632	0.15888	0.10219	0.15909	-0.43509
PAS	0.04943	0.21775	-0.17014	0.19866	-0.38644
OCC	0.08317	0.05719	0.28368	-0.38297	0.03664
OCS	0.13973	-0.03330	0.31839	-0.26204	-0.23991

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In order to filter out other confounding factors within each Principal Component, an orthogonal VARIMAX rotation of the data was performed. This type of procedure first converts the Principal Component eigenvectors into a factor matrix which maintains the relative relationship of each eigenvector to all others. Rotating a set of factors does not change the statistical explanatory powers of the factors (SAS, 1994). The VARIMAX transformation rotates the multivariate data in until it brings into resolution the greatest contributing factors present in each PC. The scores remain in factor form, but keep their relative magnitude when compared to the original PC score. An orthogonal rotation, such as VARIMAX, keeps each point of data in the same position relative to every other point of data while searching for the optimal position for the entire data set in multivariate space. Thus, although the eigenvectors are expressed as factors, the original contribution of each Principal Component (eigenvalue) remains the same, allowing the same interpretation.

Table 12 shows the rotated eigenvector matrix based upon the Principal Component Analysis detailed in Table 11. Examination of Factor 1 indicates high loadings of variables that better account for shape. In particular, facial shape is heavily weighted rather than overall cranial size (i.e. OBB, JUB, ZMB, FMB, EKB). Factor 2 shows high loadings for

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GOL, NOL, ASB, OCC, and OCS. A relatively high loading is also shown for PAC, though not above the .50 threshold. Based on the VARIMAX rotation, Factor 1 is interpreted to account for the portion of total variability explained by shape. Factor 2 is interpreted to account for the portion of total variability explained by size.

Consideration of Factor 2 in explaining total variation in the sample reveals that size contributes little to this variation. Because Factor 2 is equivalent to Principal Component 2, its contribution to explaining total variation, 13.02%, is the same. Only 13.02% of the total variation observed in these crania is due to size. A greater contribution, 50% or more, of the Principal Component associated with size would have justified further analysis into allometric scaling as a potential factor in sinus size. The variability among the samples which is accounted for in size is not sufficient to produce the distinction seen in the sinus data. Since the mean total frontal sinus area can differ by over 200% between these samples, allometric scaling due to size disparity is not a suitable candidate for consideration.

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Table 12. Principal Components Analysis of craniometrics after VARIMAX Rotation.

	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5
GOL	0.16399	**0.75758**	0.16337	0.47564	0.01359
NOL	0.11384	**0.75727**	0.18113	0.52729	0.03867
BNL	0.13336	0.12953	-0.03288	0.78768	0.33732
BBH	0.09105	0.13032	0.47176	0.14620	0.31301
XCB	0.15413	-0.16122	0.44493	-0.19143	0.05662
XFB	0.28533	-0.02921	0.52241	0.16032	0.14429
AUB	**0.65758**	0.01977	0.07953	-0.12341	0.27865
ASB	**0.50309**	**0.41269**	0.13196	-0.21060	0.14384
BPL	0.28352	0.01521	-0.30248	0.19182	0.07357
NPH	-0.07287	0.13370	0.05173	0.20701	0.75070
NLH	**0.43608**	-0.02612	-0.06228	0.28866	0.59864
OBH	0.21844	-0.04941	0.17591	-0.04214	0.67671
OBB	**0.65911**	-0.02463	0.11987	0.17977	0.17046
JUB	**0.87366**	0.13484	-0.04877	-0.00275	0.03638
NLB	0.37555	-0.13116	0.00077	0.05955	0.00224
MAB	0.26034	0.04571	0.00946	-0.25781	0.43663
ZMB	**0.54571**	-0.12101	0.09881	-0.12244	-0.00780
SSS	0.06855	-0.07281	0.01841	0.09292	-0.08785
FMB	**0.87181**	0.11642	-0.03683	0.18465	0.04350
NAS	-0.03371	0.12374	0.22204	0.73461	-0.01824
EKB	**0.91054**	0.11290	-0.03817	0.09134	-0.01152
DKB	**0.42056**	-0.15202	-0.13460	0.34117	-0.28867
WMH	-0.05978	0.19112	0.12846	0.01137	0.24790
FRC	0.02961	0.12107	0.85249	0.11540	0.06529
FRS	-0.10855	-0.13992	0.81243	0.01852	-0.01042
PAC	0.09458	**0.28950**	0.13298	0.07804	0.01641
PAS	0.03498	-0.21434	0.14468	-0.13283	0.14392
OCC	0.02545	**0.78364**	-0.06793	-0.08869	0.11315
OCS	0.09983	**0.80796**	-0.15667	0.01577	-0.04339

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Test Two: Sinus Correlation with Craniometrics

The failure of allometric scaling as a potential candidate to account for difference in frontal sinus size does not exclude individual variable scaling as a possible confounding factor. In order to search for any such variables, a multivariate ANOVA was performed on all groups. Variables which follow a pattern by testing significantly larger in the Iraqi and Egyptian samples and smaller in the Melenesian, Philippine, and Kish samples might correlate with the frontal sinus morphology established in Phase One. Both parametric and non-parametric tests were utilized in order to account for those variables which did not satisfy the assumption of normality.

Of all the variables tested, only Maximum Frontal Breadth (Table 13) and Nasal Shape (Table 14) showed an overall pattern that was consistent with the pattern established in Phase One of this study. It should be noted that non-parametric tests rank order variables and use those rank order to test difference in means. As such the resulting calculations do not produce interpretable numbers such as lower and upper confidence limits nor a difference of means value, only rejection or non-rejection at a certain alpha level.

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Table 13. Maximum Frontal Breadth ANOVA results.

Comparisons significant at the 0.05 level are indicated by '***'.

GROUP Comparison	Lower Confidence Limit	Difference Between Means	Upper Confidence Limit	
iraq - phil	1.349	5.963	10.578	***
iraq - kish	1.220	6.325	11.430	***
iraq - mel	5.426	9.708	13.991	***
iraq - egypt	2.589	9.875	17.161	***
phil - iraq	-10.578	-5.963	-1.349	***
phil - kish	-3.927	0.362	4.651	
phil - mel	0.478	3.745	7.012	***
phil - egypt	-2.828	3.912	10.652	
kish - iraq	-11.430	-6.325	-1.220	***
kish - phil	-4.651	-0.362	3.927	
kish - mel	-0.547	3.383	7.313	
kish - egypt	-3.535	3.550	10.635	
mel - iraq	-13.991	-9.708	-5.426	***
mel - phil	-7.012	-3.745	-0.478	***
mel - kish	-7.313	-3.383	0.547	
mel - egypt	-6.350	0.167	6.684	
egypt - iraq	-17.161	-9.875	-2.589	***
egypt - phil	-10.652	-3.912	2.828	
egypt - kish	-10.635	-3.550	3.535	
egypt - mel	-6.684	-0.167	6.350	

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Table 14. Nasal Shape ANOVA results.

Parametric Comparisons significant at the 0.05 level are indicated by '***'.

Non-Parametric Comparisons significant at the 0.05 level are indicated by '+++'.

GROUP Comparison	Lower Confidence Limit	Difference Between Means	Upper Confidence Limit	
iraq - phil	0.00004	0.14734	0.29464	***
iraq - kish	0.01496	0.17940	0.34383	***
iraq - mel	0.10234	0.24028	0.37822	***
iraq - egypt				+++
phil - iraq	-0.29464	-0.14734	-0.00004	***
phil - kish	-0.10467	0.03206	0.16878	
phil - mel	-0.01041	0.09294	0.19630	
phil - egypt				
kish - iraq	-0.34383	-0.17940	-0.01496	***
kish - phil	-0.16878	-0.03206	0.10467	
kish - mel	-0.06570	0.06088	0.18747	
kish - egypt				
mel - iraq	-0.37822	-0.24028	-0.10234	***
mel - phil	-0.19630	-0.09294	0.01041	
mel - kish	-0.18747	-0.06088	0.06570	
mel - egypt				
egypt- kish				
egypt- iraq				+++
egypt- mel				
egypt- phil				

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A correlation analysis was conducted on Maximum Frontal Breadth and total frontal sinus size. Since Maximum Frontal Breadth failed to meet the assumption of normality, the non-parametric Spearman's Rank Correlation was used.

The null hypothesis is that no statistically significant correlation exists between Maximum Frontal Breadth and frontal sinus size. As indicated in Table 15, the correlation failed to reject the null hypothesis at the alpha = .05 level when the missing value data subset was used.

Table 15. Non-Parametric Correlation Results of Maximum Frontal Breadth with Total Frontal Sinus Area and Perimeter - Missing Value Data Subset

	TOTAREA	TOTPERIM
Spearman Correlation Coefficients	0.23510	0.21090
Prob > |R| under Ho: Rho=0	0.0682	0.1028
Number of Observations	61	61

Table 16 indicates that the null hypothesis can be rejected at the alpha = .05 level when the zero value data subset is used. Maximum Frontal Breadth correlates with Total Frontal Sinus Area and Total Frontal Sinus Perimeter. However, both correlation coefficients show only a weak to moderate strength of association.

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Table 16. Non-Parametric Correlation Results of Maximum Frontal Breadth with Total Frontal Sinus Area and Perimeter - Zero Value Data Subset

	TOTAREA	TOTPERIM
Spearman Correlation Coefficients	0.31812	0.29882
Prob > |R| under Ho: Rho=0	0.0082	0.0133
Number of Observations	68	68

Only in the data subset where missing sinus values are substituted with zero values are we able to reject Ho in favor of Ha. Further, the correlation coefficients for TOTAREA and TOTPERIM are low and only explain approximately 30% of the variability for both TOTAREA and TOTPERIM. This leaves 70% of the variability unexplained and presumably due to other factors. In short, although Maximum Frontal Breadth does correlate with TOTAREA and TOTPERIM in one data subset, it is not a suitable candidate explaining the difference in means observed for the groups.

The ANOVA conducted on Nasal Shape, Table 14, shows the Iraqi mean Nasal Shape is significantly different than those of all other groups. However, if a direct correlation between nasal shape and total frontal sinus area does in fact exist, we should see the Egyptian sample's Nasal Shape following suit with its total frontal sinus area. In fact, the Egyptian Nasal Shape tests significantly different than the Iraqi, but not different from the rest of the samples.

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A correlation analysis was performed to further test a potential association of Nasal Shape with sinus size. The Spearman non-parametric test was chosen as Nasal Shape failed the test of normality in the Egyptian sample. Both the missing value data subset (Table 17) and the zero value data subset (Table 18) failed to produce a statistically significant correlation at alpha = .05.

The failure of Nasal Shape to reach a significant correlation at the alpha = .05 level eliminates it from consideration. Nasal Shape is not correlated with sinus size.

Table 17. Non-Parametric Correlation Results of Nasal Shape with Total Frontal Sinus Area and Perimeter - Missing Value Data Subset

	TOTAREA	TOTPERIM
Spearman Correlation Coefficients	0.13216	0.08487
Prob > |R| under Ho: Rho=0	0.3099	0.5191
Number of Observations	61	60

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Table 18. Non-Parametric Correlation Results of Nasal Shape with Total Frontal Sinus Area and Perimeter - Zero Value Data Subset

	TOTAREA	TOTPERIM
Spearman Correlation Coefficients	0.20191	0.15824
Prob > |R| under Ho: Rho=0	0.0962	0.1941
Number of Observations	69	69

Despite the failure of Maximum Frontal Breadth and Nasal Shape to correlate with sinus size, the possibility that a combination of cranial variables could account for frontal sinus size still remains. In order to test whether any combination and proportion of cranial variables might significantly explain the resulting difference in sinus size, a search for a model that maximizes adjusted r^2 was performed. The procedure included all cranial variables and was conducted on both data subsets. Since the addition of any variable to an existing multivariate regression model will automatically increase r^2, it is vital that a search for a potential explanatory regression be done to maximize adjusted r^2, not r^2(Bowerman and O'Connell, 1990).

Tables 19 and 20 detail the results of the adjusted r^2 search on the missing value data subset. Of the top five models selected, none are able to explain more approximately 30% of the variation present in either frontal sinus total

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area or perimeter. The same is true of the zero value data subset, Tables 21 and 22.

Table 19. Regression Models for Dependent Variable: TOTAREA. Missing Value Data Subset.

N = 56

Adj Rsq	R-square	In	Variables in Model
0.307077	0.470859	13	NOL XFB AUB BPL NPH OBH FMB NAS EKB FRC PAC PAS OCC
0.305382	0.444305	11	BNL XFB AUB OBH JUB NLB SSS FMB EKB PAC PAS
0.305087	0.456705	12	NOL XFB AUB BPL NPH OBH FMB EKB FRC PAC PAS OCC
0.304947	0.456595	12	NOL XFB BPL NPH OBH FMB NAS EKB FRC PAC PAS OCC
0.304292	0.456083	12	BNL XFB AUB NPH OBH JUB NLB SSS FMB EKB PAC PAS

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Table 20. Regression Models for Dependent Variable: TOTPERIM. Missing Value Data Subset.

N = 56

Adj Rsq	**R-square**	**In**	**Variables in Model**
0.315587	0.477357	13	NOL XFB AUB BPL NPH OBH ZMB FMB EKB FRC PAC PAS OCC
0.311301	0.486606	14	NOL XFB AUB ASB BPL NPH OBH ZMB FMB EKB FRC PAC PAS OCC
0.310324	0.460799	12	NOL XFB AUB BPL NPH OBH ZMB FMB FRC PAC PAS OCC
0.309910	0.498116	15	NOL XFB AUB ASB BPL NPH OBH ZMB FMB EKB FRC PAC PAS OCC OCS
0.309685	0.485401	14	NOL XFB AUB BPL NPH OBH ZMB FMB EKB FRC FRS PAC PAS OCC

Table 21. Regression Models for Dependent Variable: TOTAREA. Zero Value Data Subset.

N = 63

Adj Rsq	**R-square**	**In**	**Variables in Model**
0.289275	0.403908	10	XFB AUB ASB NLH OBH JUB NLB FMB PAS OCC
0.288389	0.391687	9	XFB AUB ASB NLH JUB NLB FMB PAS OCC
0.285835	0.412542	11	XFB AUB ASB NLH OBH JUB NLB FMB NAS PAS OCC
0.285724	0.400930	10	XFB AUB ASB NLH OBH NLB FMB EKB PAS OCC
0.285576	0.412328	11	XFB AUB ASB NLH OBH JUB NLB FMB EKB PAS OCC

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Table 22. Regression Models for Dependent Variable: TOTPERIM. Zero Value Data Subset.

N = 63

Adj Rsq	R-square	In	Variables in Model
0.308672	0.453628	13	XFB AUB ASB NLH OBH JUB NLB FMB WMH FRC FRS PAS OCC
0.307947	0.441893	12	XFB AUB ASB NLH JUB NLB FMB WMH FRC FRS PAS OCC
0.304927	0.428246	11	XFB AUB ASB NLH JUB NLB FMB FRC FRS PAS OCC
0.304828	0.450590	13	XFB AUB ASB NLH JUB NLB FMB WMH FRC FRS PAS OCC OCS
0.304647	0.461662	14	XFB AUB ASB NLH OBH JUB NLB MAB FMB WMH FRC FRS PAS OCC

This type of search seeks the regression model, which best predicts the dependent dependent variable without regard to subjective analysis of the independent variables included within it. In other words, a more direct and careful approach involves the analysis of each variable's justification for inclusion and thus produces a more logical and theoretically salient model, but not one with as high a r^2. Since all of the above models have a r^2 of approximately .30, it can be said that in the best case scenario, only approximately 30% of the variability witnessed in frontal sinus size can be attributed to the cranial variables. This rules out cranial variation as an explanation for the sinus size differences noted between the sample groups included in this study.

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Test Three: Environmental Variables

The failure of Test One and Test Two to locate the source of sinus difference within allometric scaling and cranial variation leads this study to the next and final stage of analysis. A database was obtained from the National Climatic Data Center, National Oceanic and Atmospheric Administration that includes daily climate summaries from 10,000+ stations around the world from 1977-1991. Datasets were extracted and compiled utilizing station locations which are most representative of the geographic distribution of the skeletal samples included in this study.

The data were sorted and processed to produce the mean, standard deviation, minimum, and maximum scores for each of the climatic variables used on a monthly basis. Plots were generated by area. Detailed analysis of these climate plots reveals several trends.

First, if temperature is tracked through several months, a sharp variation is noticed in the Iraqi data set (Figure 3). The monthly mean for the average daily temperature swings from 7.05 degrees Celsius in January to 35.56 degrees Celsius in July, a difference of 28.51 degrees Celsius.

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```
                       Plot of MAXMEAN*MONTH.  Symbol used is '+'.
                       Plot of AVGMEAN*MONTH.  Symbol used is '*'.
                       Plot of MINMEAN*MONTH.  Symbol used is '-'.

        --+------+------+------+------+------+------+------+------+------+------+------+--
     60 +                                                                                +
        |                                                                                |
        |                                                                                |
        |                                                                                |
        |                                                                                |
        |                                                                                |
        |                                           +      +                             |
     40 +                                    +                                           +
        |                             +                           +                      |
        |                                           *      *                             |
TEMP    |                                    *                           +               |
        |                      +      *                           *                      |
        |                                           -      -             *               |
        |               +      *             -                                           |
     20 +                             -                           -             +        +
        |               *      -                                         -               |
        |        +                                                              *      + |
        | +             -                                                       -      * |
        |        *                                                                       |
        | *      -                                                                     - |
        | -                                                                              |
      0 +                                                                                +
        --+------+------+------+------+------+------+------+------+------+------+------+--
          1      2      3      4      5      6      7      8      9     10     11     12

                                              MONTH
```

Figure 3. Yearly Temperature Cycle for Iraq.

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Egypt (Figure 4) follows a similar, but less radical pattern with a January monthly mean for the average daily temperature of 14.35 degrees Celsius jumping to 27.47 degrees Celsius in July, a difference of 13.12 degrees Celsius.

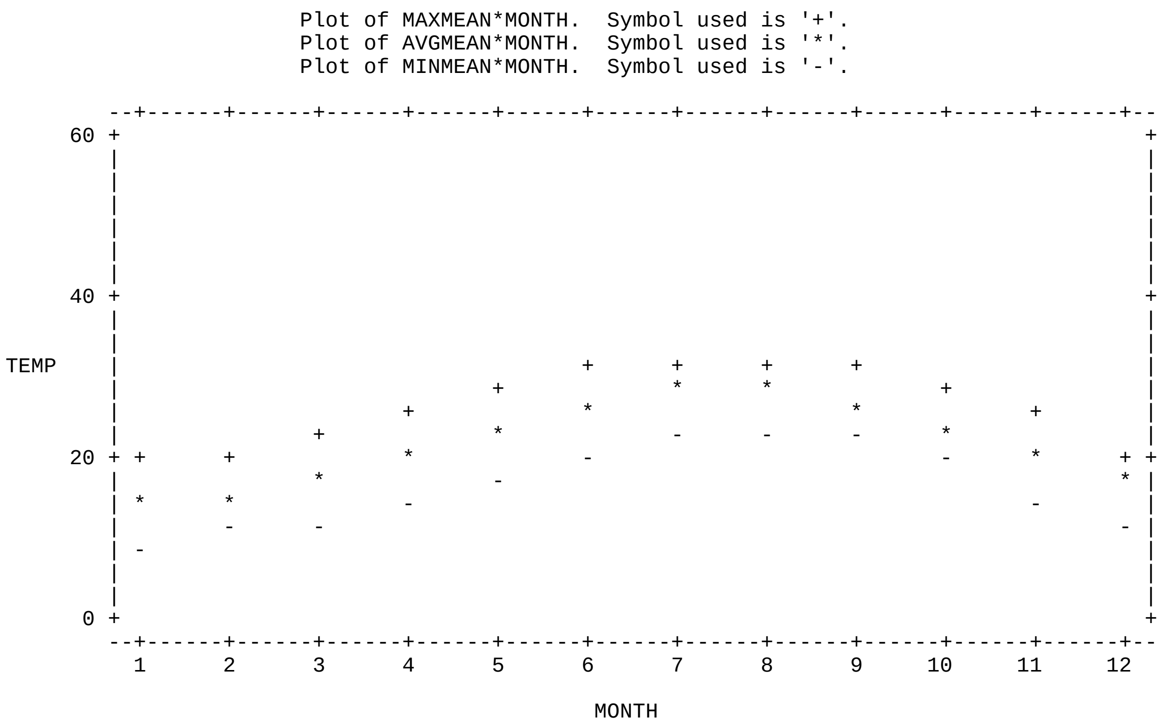

Figure 4. Yearly Temperature Cycle for Egypt.

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Papua New Guinea (Figure 5) experiences its coolest month in July with a monthly mean for average daily temperature of 26.75 degrees Celsius. The hottest month occurs in January with a monthly mean for the average daily temperature of 27.81 degrees Celsius, a difference of .06 degrees Celsius.

```
                 Plot of MAXMEAN*MONTH.  Symbol used is '+'.
                 Plot of AVGMEAN*MONTH.  Symbol used is '*'.
                 Plot of MINMEAN*MONTH.  Symbol used is '-'.

       --+------+------+------+------+------+------+------+------+------+------+------+--
    60 +                                                                                 +
       |                                                                                 |
       |                                                                                 |
       |                                                                                 |
       |                                                                                 |
       |                                                                                 |
       |                                                                                 |
    40 +                                                                                 +
       |                                                                                 |
       |                                                                                 |
TEMP   |                                                                                 |
       | +      +      +      +      +      +      +      +      +      +      +      +  |
       | -      -      -      -      -      -      *      *      *      -      -      -  |
       |                                                                                 |
    20 +                                                                                 +
       |                                                                                 |
       |                                                                                 |
       |                                                                                 |
       |                                                                                 |
       |                                                                                 |
       |                                                                                 |
     0 +                                                                                 +
       --+------+------+------+------+------+------+------+------+------+------+------+--
         1      2      3      4      5      6      7      8      9      10     11     12

                                            MONTH
```

Figure 5. Yearly Temperature Cycle for Papua New Guinea.

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The Philippines (Figure 6) experience their coolest month in January with a monthly mean for the average daily temperature of 26.42 degrees Celsius. The hottest monthly mean for the average daily temperature occurs in May at 29.28 degrees Celsius, a difference of 2.86 degrees Celsius.

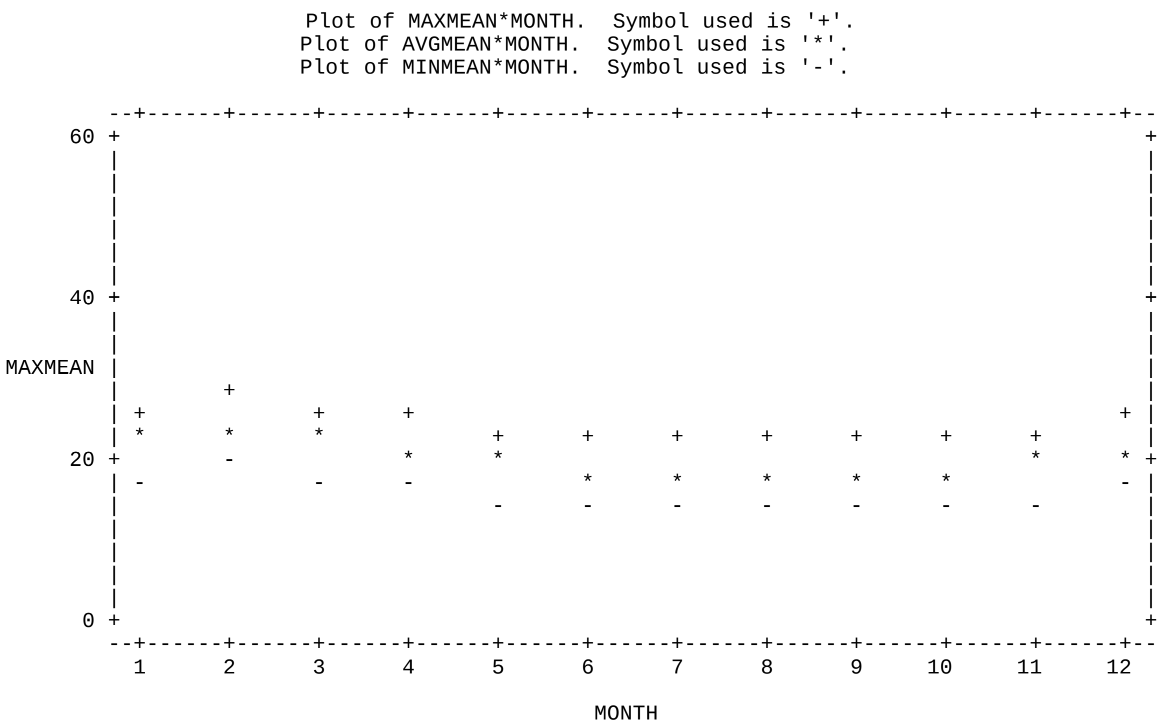

Figure 6. Yearly Temperature Cylce for Peru.

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Finally, the areas surrounding Marquez, Peru (Figure 7) experience their coolest month in August with a monthly mean for the average daily temperature of 17.27 degrees Celsius. The hottest month occurs in February with a monthly mean for the average daily temperature of 22.92 degrees Celsius, a difference of 5.65 degrees Celsius.

```
                         Plot of MAXMEAN*MONTH.  Symbol used is '+'.
                         Plot of AVGMEAN*MONTH.  Symbol used is '*'.
                         Plot of MINMEAN*MONTH.  Symbol used is '-'.

        --+------+------+------+------+------+------+------+------+------+------+------+--
     60 +                                                                                +
        |                                                                                |
        |                                                                                |
        |                                                                                |
        |                                                                                |
        |                                                                                |
        |                                                                                |
     40 +                                                                                +
        |                                                                                |
        |                      +      +                                                  |
TEMP    | +      +      +                    +      +      +      +      +      +      + |
        |               *      *      *      *      *      *      *      *      *        |
        | *      *                    -      -      -      -      -                    * |
        | -      -      -      -                                         -      -      - |
     20 +                                                                                +
        |                                                                                |
        |                                                                                |
        |                                                                                |
        |                                                                                |
        |                                                                                |
        |                                                                                |
      0 +                                                                                +
        --+------+------+------+------+------+------+------+------+------+------+------+--
          1      2      3      4      5      6      7      8      9     10     11     12

                                             MONTH
```

Figure 7. Yearly Temperature Cycle for the Philippines.

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The above descriptions are summarized and sorted by difference in Table 23.

Table 23. Yearly Temperature Cycle Summary for Sample Areas.

Locality	Max Avg Temp	Min Avg Temp	Difference
Iraq	35.56	7.05	28.51
Egypt	27.47	14.35	13.12
Peru(Marquez)	22.92	17.27	5.65
Philippines	29.28	26.42	2.86
Papua New Guinea	27.81	26.75	0.06

In order to better compare the true yearly variation in temperature due to seasonal shifts, a coefficient of variation calculation was performed. Since CV is only appropriate for ratio scale data (Zar, 1984), individual temperatures were first converted from degrees Celsius, an interval scale, to degrees Kelvin, a ratio scale.

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The pattern presented in Table 24, with the exception of the Peruvian and Kish data, seems to loosely coincide with the pattern displayed by each group's mean total frontal sinus area. A plot of total frontal sinus area by climate CV (Figure 8) illustrates this trend.

Table 24. Coefficient of Variation of Yearly Temperature Fluctuation.

Locality	CVMAXTMP	CVAVGTMP	CVMINTMP
Iraq	3.98106	3.58063	3.98106
Egypt	2.13294	1.92501	2.13294
Peru	1.19914	1.33381	1.19914
Phil	0.73619	0.56214	0.73619
Mel	0.49353	0.44743	0.49353

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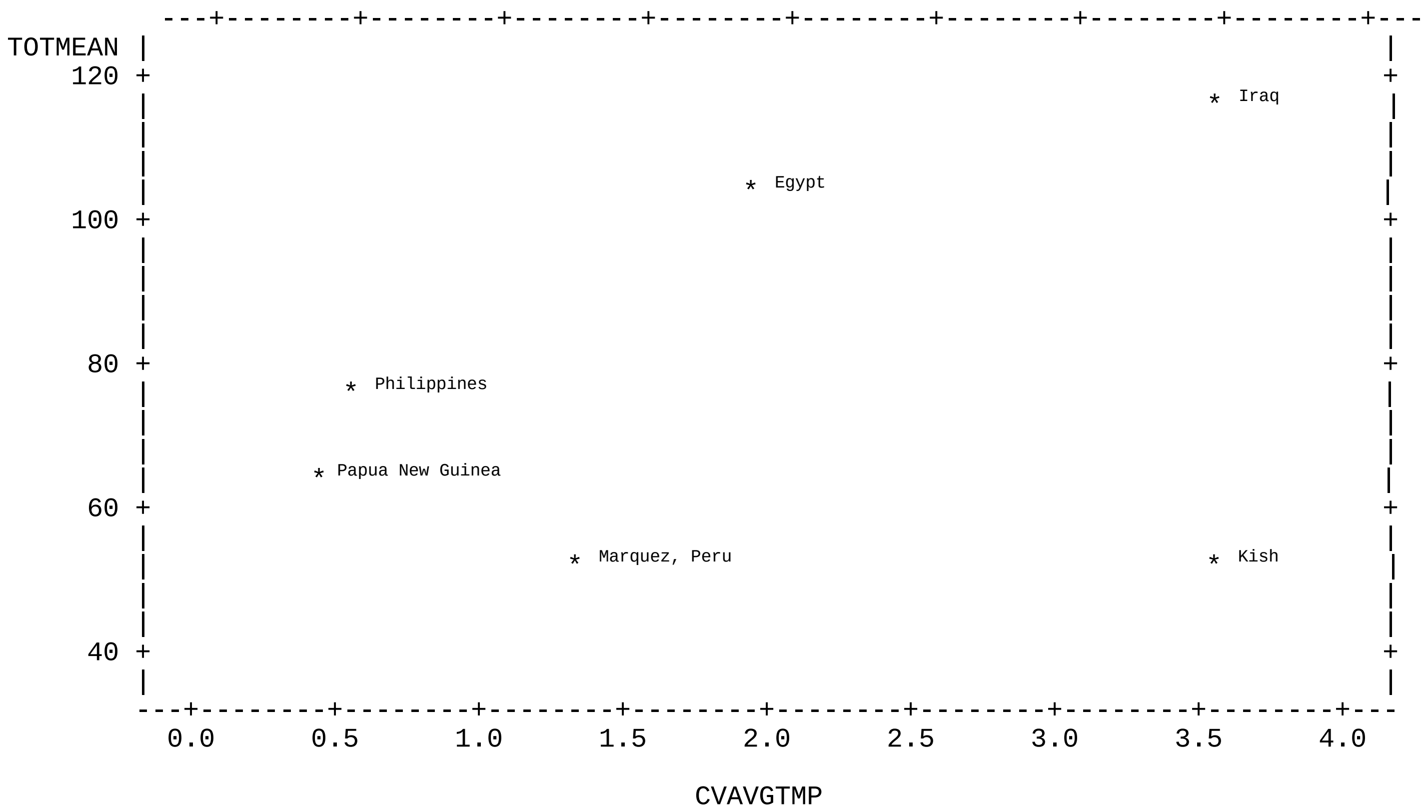

Figure 8. Plot of Mean Total Frontal Sinus Area*Average Tmp CV by Group

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The plot of total frontal sinus size indicates a potential positive correlation. Data for the Melanesian, Philippine, Egyptian, and Iraqi samples indicate that as the seasonal variation increases the average total frontal sinus area increases with it. The exceptions to the above potential correlation lie in the Kish and the Peruvian samples.

A correlation analysis was performed on total frontal sinus area and perimeter, with the coeffiecient of variation for yearly temperature for the missing value data subset (Table 25 and 26) and the zero value data subset (Table 27 and 28).

Table 25. Total Area with CVAVGTMP - Missing Value Data Subset

Pearson Correlation Coefficients	0.21078
Prob > |R| under Ho: Rho=0	0.0676
Number of Observations	76

Table 26. Total Perimeter with CVAVGTMP - Missing Value Data Subset

Spearman Correlation Coefficients	0.15412
Prob > |R| under Ho: Rho=0	0.1868
Number of Observations	75

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Table 27. Total Area with CVAVGTMP - Zero Value Data Subset

Pearson Correlation Coefficients	0.23788
Prob > |R| under Ho: Rho=0	0.0293
Number of Observations	84

Table 28. Total Perimeter with CVAVGTMP - Zero Value Data Subset

Spearman Correlation Coefficients	0.18652
Prob > |R| under Ho: Rho=0	0.0894
Number of Observations	84

Only total area in the zero value data subset, Table 27, showed significance at the alpha = .05 level. However, the coefficient of correlation is very weak at 0.23788. All other tests, Tables 25, 26, 28, failed significance at the alpha = .05 level. No correlation between frontal sinus size and the seasonal variability in temperature is presented in this dataset.

Despite the failed correlation, the association between sinus size and the coefficient of variation for average annual temperature remains compelling. The dataset used for the correlations in Tables 25, 26, 27, and 28 was reevaluated. As was discussed in Phase One, the Kish sample tests significantly different in nasal form, indicating that it may indeed come from a region and/or time period which is

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more similar in temperature and humidity to the Melanesian and Philippine samples. Thus, the associated CV for annual average temperature would not apply as it is currently plotted.

The Peruvian sample presents more of a problem. As it is dated to approximately 900-1500 A.D. and with somewhat better contextual information, temporal climate shift and populational affinity are less likely explanations. However, individuals from this group all experienced cranial deformation and it is yet unclear how this modification may impact on frontal sinus development.

An exploratory hypothesis was designed around the above observations. In order to test the hypothesis that frontal sinus area is correlated with the amount of variability in seasonal climatic shifts, a number of assumptions have to be made. First, based on nasal shape, Kish may derive from a population not representative of the modern Iraqi population and will be dropped from the dataset. Second, due to unknown impact of cranial deformation on frontal sinus development, the Peruvian sample will also be dropped from the dataset. Both these assumptions are untested and speculative, but given the relatively secure contextual placement of the remaining samples, I believe these exclusions are warranted in an exploratory sense. It must be stressed, however, that this modification of the original

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dataset is not valid until the assumptions which remove the Kish and Peruvian samples can be verified.

Correlation analysis on the modified dataset reveals a significant association of total frontal sinus area and perimeter with regional seasonal temperature shift intensity. In particular, TOTAREA is well correlated with .57 and .55 for the missing value data subset, Table 29, and zero value data subset, Table 31. Total sinus perimeter also correlates significantly at a coeffiecient of around .50 for both data subsets, Tables 30 and 32. These correlations can be considered strong as this test was performed with the entire data set represented, and thus the entire range of variation impacts on the line fitted to the curve.

Table 29. Total Area with CVAVGTMP - Modified Missing Value Data Subset

Pearson Correlation Coefficients	0.57294
Prob > |R| under Ho: Rho=0	0.0001
Number of Observations	53

Table 30. Total Perimeter with CVAVGTMP - Modified Missing Value Data Subset

Spearman Correlation Coefficients	0.49075
Prob > |R| under Ho: Rho=0	0.0002
Number of Observations	53

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Table 31. Total Area with CVAVGTMP - Modified Zero Value Data Subset

Pearson Correlation Coefficients	0.55246
Prob > |R| under Ho: Rho=0	0.0001
Number of Observations	60

Table 32. Total Perimeter with CVAVGTMP - Modified Zero Value Data Subset

Spearman Correlation Coefficients	0.48755
Prob > |R| under Ho: Rho=0	0.0001
Number of Observations	60

If this variation is extracted by performing the correlation utilizing group means in place of individual observations, Table 33, the correlation becomes extremely strong. A systematic pattern in frontal sinus size has been established with statistically significant difference of means. Utilizing those means rather than individual observations preserves inter-group variability but eliminates intra-group variability.

Although the test in Table 33 may seem suspect at first due to the low number of observations used (n=4), the correlation remains valid for two reasons. First, both variables, the coefficient of variation for yearly average daily temperature and the group mean for total frontal sinus data, are based on very large datasets. Second, the

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probability value for Pearson's Correlation Coefficient is calculated based on the t-distribution with n-2 degrees of freedom. A significant finding (alpha = .05) with this number of observations is extremely difficult unless a true relationship exists. For these reasons I believe the exploratory correlations presented above are valid.

Table 33. Group Mean Total Area with CVAVGTMP - Modified Missing Value Data Subset

Pearson Correlation Coefficients	0.95728
Prob > |R| under ho: Rho=0	0.0427
Number of Observations	4

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CHAPTER 4

DISCUSSION

The Frontal Sinuses

The establishment of systematic patterning in frontal sinus size among geographically distinct groups was key to this study. Further analysis would be unwarranted if no difference could be observed from one group to another. The results of Phase One of this study demonstrated that the geographically distinct samples used have statistically significant differences in mean frontal sinus size. Further, the parametric nature of the data, also established in Phase One, allowed the use of the most robust method for testing difference of means, Student's t. The differences present in the samples even outweighed the extraordinary intra-group variability present in the frontal sinus metrics, emphasizing the reality of group distinctiveness in frontal sinus size.

Overall, the six geographic samples separated into two distinct groups. The Iraqi and Egyptian samples clustered together with the greatest total frontal sinus area. The Iraqis possess a greater, but not significantly different, mean than the Egyptians. The Melanesian, Philippine, Peruvian, and Kish samples cluster together with a much smaller aggregate mean of about one half the area that is

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seen in the Iraqi and Egyptian samples. The Philippine, the largest of this group, tends to not test significantly different than the Egyptian in some instances, but this may be due to an extreme outlier in the sample. The Peruvian and the Kish show a mean at the low end of the spectrum, but still not one statistically different than the rest of this group.

Craniometrics

A systematic search for contributing factors to the systematic patterning found frontal sinus size was initiated. Overall cranial form is considered the first candidate for this patterning. Size, and the resulting allometric scaling, is often a confounding factor in morphologic investigation (Bookstein, 1991). In order to evaluate the potential impact of size, and to establish the need for data calibration, a series of multivariate techniques were utilized begining with a Principal Components Analysis. The initial Principal Components Analysis resulted in eigenvectors of an extremely low weighting, which indicated a failure of the analysis to partition the Principal Components into singular explanatory units (i.e. size, shape, etc.). In order to remove the "noise" contained in the original Principal Components Analysis, a VARIMAX rotation of the data was performed.

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Since this rotation is orthogonal in nature, the relationship between the Principal Components and the data remains static. Only the eigenvectors, now called factors, change their loading on individual variables. With this accomplished, a pattern emerged in which the first Principal Component is related to facial shape, while the second Principal Component is related to size. Since the second Principal Component only accounts for 13% of the variation among all the groups tested, size could ruled out as a potential explanation for the difference in means in frontal sinus size.

Next, a search for potential candidates in individual variables was conducted. A series of parametric and non-parametric ANOVAs was performed. In order to be a viable candidate for a bivariate correlation, the variable must exhibit the same pattern established in the frontal sinuses. In other words, if in the Papua New Guinea dataset, it must test significantly different from the Iraq/Egyptian. Two such variables were found; maximum frontal breadth (XFB) and nasal shape (NRATIO). Intuitively, both of these are potentially robust in their relation to frontal sinus variation. A larger maximum frontal breadth would mean a proportionately frontal sinus if no other factor impacts upon their development.

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Similarly, the established link between nasal shape and the environment (Wolpoff, 1968) presents another potential candidate. Since the frontal sinus communicates directly with the middle meatus through the fronto-naso duct (Shankar, et al., 1994), a direct correlation would exist if the sinus were under the exact adaptive pressure as nasal form.

Analyses performed to test the association of Maximum Frontal Breadth and Nasal Shape with sinus size revealed weak correlations in both cases which were unable to statistically satisfy the above relationships. These variables alone cannot account for differential sinus size in this sample.

Finally, in an attempt to explore a potentially cryptic relationship between frontal sinus size and a combination of cranial variables, a regression procedure was performed which searched for a model that maximizes adjusted r^2. It is vital to use adjusted r^2 for this procedure, as normal (non-adjusted) r^2 will automatically increase with the addition of another variable into the model (Bowerman and O'Connell, 1990). The use of non-adjusted r^2 will produce an artificially inflated result. The results of the best 5 models failed to reach an adjusted r^2 of above .30, indicating that under the best circumstances, only 30% of

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the patterned variation in frontal sinus size can be explained by craniometrics.

In sum, the craniometric data failed to relate in a significant way to the inter-group variation demonstrated in Phase One of this study. As such, it was necessary to look outside of skeletal form for a potential candidate.

The Environment

Through the use of an extensive collection of data compiled by the NOAA, a working database was developed which matched, as closely as possible, the geographic affinity of each of the sample groups. Although the samples were originally chosen based on the Koppen-Geiger system of climatic classification, the NOAA database allows an extremely accurate method for determining the exact climate a given population experiences. While the Koppen-Geiger system allows for accurate, but broad, generalizations of climate type, only with the use of daily summaries like those provided by NOAA can truly testable climate patterns be established.

The climate data were sorted and monthly averages for daily minimum, maximum, average temperature and daily precipitation were produced. The temperature data were then plotted by geographic location. A pattern emerges for each location. The Iraqi and Egyptian localities experience a

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"spike" in monthly mean temperature during the month of July and a severe depression in the month of January. All other localities experience a flux in monthly mean temperature, but to a much lesser degree.

What emerges in the climate data is roughly the same pattern seen in frontal sinus size. That is, Iraq and Egypt appear at the top of the range, while all others sort to the bottom of the range. To better test this relationship, a Coefficient of Variation was calculated on the Mean Annual Average Daily Temperature. This calculation accomplished two things. First, using the Mean Annual Average Daily Temperature captures the variation of the entire year, not a polarity which only uses the coldest and hottest months. Second, the Coefficient of Variation corrects for the magnitude of the data by expressing sample variability relative to the mean of the sample (Zar, 1985). CVAVGTMP is a measure of annual temperature variation which is standardized with respect to differences in mean annual temperature between sample sites.

A plot of the CVAVGTMP and the group means for total frontal sinus area revealed an interesting trend. A linear relationship appeared between the Melanesian, Philippine, Egyptian, and Iraqi samples. The Peruvian and Kish samples fell out to the bottom of the chart. A correlation analysis

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performed on this potential association failed to reach statistical significance.

The inclusion of the Peruvian and Kish samples within this study was reevaluated and an exploratory modification was proposed. The effects of cranial boarding on the development of the frontal sinus is yet unknown. One possible impact could be a restriction in the development of the sinus by binding the frontal bone during adolesent development, thus artificially decreasing the resulting frontal sinus size seen in adulthood. For the purposes of this exploratory testing, this was considered a genuine possibility and warranted the exclusion of the Peruvian material.

The Kish sample was reevaluated based on two fronts. First, preliminary paleoclimatic analysis indicates that Mesopotamia may have had a climate different than that of today. If so, it would be unreasonable to apply the CVAVGTMP to the Kish sample. Second, and supporting the first, the nasal shape of the Kish sample tests significantly different from that of the Iraqi sample. If nasal shape does indeed correlate well with climatic conditions, the Kish sample derives from a climatically different environment than the modern Iraqi sample, warranting its exclusion.

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The above assumptions were incorporated into the model and an analysis was performed. A correlation analysis between individual total frontal sinus area showed a coefficient of .57 for the data subset excluding missing sinus values and .55 for the data subset counting missing sinus values as zero. While these values initially seem moderate in strength, I propose that they are indeed strong. Since the test was performed using individual observations, not group means, within-group variability drags the coefficient down. A second test, one with group mean total frontal sinus area, was developed. Since it was shown that the means are significantly different, this approach is justified. Using the group mean rather than individual observations maintains inter-group variability, but removes intra-group variability. Rather than collapsing the data into two groups, Iraq/Egypt and Melanesian/Philippine, a step that would be justified, the data sets were kept distinct to better capture the linear relationship.

The correlation between group mean total frontal sinus area and the Coefficient of Variation for Mean Yearly Average Daily Temperature becomes extremely strong at .95. Further, the probability of the correlation model is significant at alpha = .05. As stated before, since the probability for Pearson’s Correlation Coefficient is based

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on the t-distribution with n-2 degrees of freedom, the correlation is valid despite its small sample size.

Interpretation and Conclusion

Analysis of this data set has shown that systematic differences in frontal sinus size cannot be explained by allometric scaling and/or cranial variation. While cranial shape and size do differ between samples in this data set, the variation is minimal when compared to the differences observed in sinus size.

Previous studies on frontal sinus variation have commented on the apparent relationship between the sinus morphology and climate. Some have posited that frontal sinus size might be influenced by differential temperature and humidity between regions, i.e. colder environments produce smaller sinuses or more humid environments show expansion in sinus size. These hypotheses, however, have failed to test statistically significant. All studies are consistent when focusing on the environment in looking at whether one region is colder or hotter, drier or more humid than the other. Intra-regional variability has been ignored.

The analysis of this set of data suggests that the key to understanding frontal sinus variation is not in inter-regional climatic variation, but in intra-regional climatic

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differences. A “stable” climate, one that fluctuates relatively little within each yearly cycle, seems to be linked with a reduction in frontal sinus size. A “deep-cycling” climate, one that fluctuates an enourmous amount, seems to be linked with an expansion in frontal sinus size. Because so little is known about the physiologic function of the frontal sinus, reasons for this association would be purely speculative.

Further, though not tested in this study, I believe that it is the upper end of this variation which is the driving force of sinus expansion. This study has shown a correlation between the CVAVGTMP and sinus size, but this simplified model most likely will not apply in extreme northerly latitudes where sinus size appears to decrease as samples are drawn closer to the Arctic (Hylander, 1977). These northerly latitudes might experience a CVAVGTMP similar to Iraq, but never reach the extreme heat of Iraq. That is, they may fluctuate from extreme cold to moderate temperatures, but not from below freezing to extremely hot temperatures. In addition, it may be possible that those populations residing in northerly latitudes experience an effective decrease in CVAVGTMP due to cultural adaptations, while populations residing in areas such as Iraq have less of an ability to effectively modify temperature exposure.

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All of the above suggestions lie outside the scope of this study and are merely explorations in potential logic.

In summary, the above study has documented a statistically systematic patterning in frontal sinus size. Further, allometric scaling and cranial variation have been discounted as driving forces behind frontal sinus disparity.

Though climate failed to add any additional information when using the original data set, an exploratory analysis revealed potentially important informtion. The exploratory analysis demonstrated an effective relationship between intra-regional climate variation and frontal sinus size within the modified dataset. However, none of the relationships posited in this exploratory analysis can be applied unless further investigation validates the exclusion of the Kish and Peruvian samples. A demonstration of biologic affinity other than Iraqi or conclusive evidence for climatic dissimilarity with modern-day Iraq would be needed for the Kish sample. Increased knowlege of the effects of cradle boarding on cranial development with particular attention to the frontal bone in needed in the Peruvian's case. Further, even with such a validation, these results cannot be applied at a global scale until the sample range is increased and further testing is performed.

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Appendix A. Frontal Sinus Metrics Summary Statistics

Missing Value Data Subset

GROUP	N Obs	Variable	N	Mean	Std Dev	Minimum	Maximum
Egypt	3	LAREA	3	56.2541326	19.3024504	42.5355839	78.3264165
		RAREA	3	46.8964994	23.4274647	19.9736014	62.6414268
		TOTAREA	3	103.1506320	6.5043340	98.3000178	110.5418244
		LPERIM	3	105.3683000	33.8856275	83.1065400	144.3657600
		RPERIM	3	81.1209967	20.6592668	57.2675400	93.3022000
		TOTPERIM	3	186.4892967	13.4577474	175.8997900	201.6333000
Iraq	8	LAREA	8	48.7493853	23.7717145	20.4632589	79.1576929
		RAREA	8	66.6142371	22.7018865	42.2093302	98.1245422
		TOTAREA	8	117.5196729	33.9952921	75.0992923	172.5503535
		LPERIM	8	91.3191425	26.1613036	57.6633000	128.1359900
		RPERIM	8	101.0130888	19.1253388	78.8348000	131.9718500
		TOTPERIM	8	199.3903813	36.8265577	143.3074800	260.1078400
Kish	10	LAREA	8	31.5440214	21.7850929	13.7962787	78.3264165
		RAREA	8	25.4533478	17.7222908	11.7052677	57.1566716
		TOTAREA	9	51.5041460	30.0223506	11.7052677	100.7637702
		LPERIM	7	64.3241171	16.3512734	49.5019500	93.4752500
		RPERIM	8	58.0994025	24.5144106	36.9135000	102.8675000
		TOTPERIM	8	119.6967750	49.1128079	38.8740800	196.3427500
Melenesia	30	LAREA	25	24.8307317	14.8611023	1.4217274	57.4799317
		RAREA	25	33.2630145	16.0700710	6.0414156	71.8498700
		TOTAREA	25	62.3685857	29.3612173	14.3677335	129.3298017
		LPERIM	25	62.4883232	23.4280202	14.5405500	108.6029400
		RPERIM	25	67.3045468	21.1284709	29.4954000	123.4723200
		TOTPERIM	25	139.6528640	45.3319562	71.3745000	242.8942500
Peru	14	LAREA	14	26.0144032	9.1860131	7.9882449	43.3587560
		RAREA	14	23.9054675	11.3365797	4.3660811	39.6671053
		TOTAREA	14	50.9663041	15.6708324	12.3543260	72.9355467
		LPERIM	14	63.8117879	13.6541367	37.1265400	87.8962000
		RPERIM	14	56.3209129	15.7632649	24.3557400	79.9338900
		TOTPERIM	14	124.1416771	25.0964587	61.4822800	162.3986000
Phil.	19	LAREA	17	35.1461911	14.1167582	16.4312192	72.1796413
		RAREA	17	39.7099487	15.9861438	14.0471893	73.4728714
		TOTAREA	17	74.8561398	26.1168728	36.4058273	145.6525127
		LPERIM	17	77.0137312	15.0345010	52.6618400	118.1124000
		RPERIM	17	76.6382347	20.1606997	44.2174800	129.1911600
		TOTPERIM	17	153.6519659	30.7124762	116.9870400	247.3035600

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Zero Value Data Subset

GROUP	N Obs	Variable	N	Mean	Std Dev	Minimum	Maximum
Egypt	3	LAREA	3	56.2541326	19.3024504	42.5355839	78.3264165
		RAREA	3	46.8964994	23.4274647	19.9736014	62.6414268
		TOTAREA	3	103.1506320	6.5043340	98.3000178	110.5418244
		LPERIM	3	105.3683000	33.8856275	83.1065400	144.3657600
		RPERIM	3	81.1209967	20.6592668	57.2675400	93.3022000
		TOTPERIM	3	186.4892967	13.4577474	175.8997900	201.6333000
Iraq	8	LAREA	8	48.7493853	23.7717145	20.4632589	79.1576929
		RAREA	8	66.6142371	22.7018865	42.2093302	98.1245422
		TOTAREA	8	117.5196729	33.9952921	75.0992923	172.5503535
		LPERIM	8	91.3191425	26.1613036	57.6633000	128.1359900
		RPERIM	8	101.0130888	19.1253388	78.8348000	131.9718500
		TOTPERIM	8	199.3903813	36.8265577	143.3074800	260.1078400
Kish	10	LAREA	10	25.2352171	23.3670527	0	78.3264165
		RAREA	10	20.3626782	18.9594708	0	57.1566716
		TOTAREA	10	46.3537314	32.6567020	0	100.7637702
		LPERIM	10	45.0268820	33.8183516	0	93.4752500
		RPERIM	10	46.4795220	32.6727192	0	102.8675000
		TOTPERIM	10	95.7574200	66.5066279	0	196.3427500
Melenesia	30	LAREA	30	20.6922765	16.4730485	0	57.4799317
		RAREA	30	27.7191788	19.3052160	0	71.8498700
		TOTAREA	30	51.9738214	35.6697566	0	129.3298017
		LPERIM	30	52.0736027	31.8633351	0	108.6029400
		RPERIM	30	56.0871223	31.9420199	0	123.4723200
		TOTPERIM	30	116.3773867	67.1030723	0	242.8942500
Peru	14	LAREA	14	26.0144032	9.1860131	7.9882449	43.3587560
		RAREA	14	23.9054675	11.3365797	4.3660811	39.6671053
		TOTAREA	14	50.9663041	15.6708324	12.3543260	72.9355467
		LPERIM	14	63.8117879	13.6541367	37.1265400	87.8962000
		RPERIM	14	56.3209129	15.7632649	24.3557400	79.9338900
		TOTPERIM	14	124.1416771	25.0964587	61.4822800	162.3986000
Phil.	19	LAREA	19	31.4465920	17.3188748	0	72.1796413
		RAREA	19	35.5299541	19.5940665	0	73.4728714
		TOTAREA	19	66.9765461	34.1082167	0	145.6525127
		LPERIM	19	68.9070226	28.1169713	0	118.1124000
		RPERIM	19	68.5710521	30.7440959	0	129.1911600
		TOTPERIM	19	137.4780747	56.4405548	0	247.3035600

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Appendix B. Climate Summary Statistics by Month

MONTH=1

AREA	N Obs	Variable	N	Mean	Std Dev	Minimum	Maximum
Egypt	1160	MAXTMP	1160	18.8554310	3.0662523	10.6000000	32.0000000
		AVGTMP	1160	14.3593966	2.4931403	7.3000000	25.0000000
		MINTMP	1160	9.8633621	3.4950986	-0.2000000	18.8000000
		PRECIP	1160	0.7739655	3.2087232	0	51.0000000
Iraq	446	MAXTMP	446	12.2109865	3.4600306	2.6000000	28.2000000
		AVGTMP	446	7.0520179	3.0440597	-0.4500000	18.8000000
		MINTMP	446	1.8930493	3.7884059	-9.3000000	11.7000000
		PRECIP	446	0.7334081	2.5712377	0	26.0000000
Mel.	1041	MAXTMP	1041	29.8155620	1.5559093	24.1000000	39.7000000
		AVGTMP	1041	27.8086936	1.2988878	21.2500000	32.1500000
		MINTMP	1041	25.8018252	1.9925791	12.2000000	30.4000000
		PRECIP	1041	8.0440922	15.6787873	0	189.0000000
Peru	1172	MAXTMP	1172	26.6885666	3.4430026	16.0000000	37.0000000
		AVGTMP	1172	22.2949232	4.0195925	10.5000000	31.0000000
		MINTMP	1172	17.9012799	5.0280518	1.0000000	27.0000000
		PRECIP	1172	0.5590444	2.8348168	0	44.3000000
Phil.	1572	MAXTMP	1572	30.6571247	2.1744992	20.5000000	37.0000000
		AVGTMP	1572	26.4196247	1.6588453	18.1000000	31.1500000
		MINTMP	1572	22.1821247	2.2186278	12.6000000	27.7000000
		PRECIP	1572	1.9433842	7.8689028	0	115.0000000

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--- MONTH=2 ---

AREA	N Obs	Variable	N	Mean	Std Dev	Minimum	Maximum
Egypt	1087	MAXTMP	1087	20.0712052	3.9450308	10.0000000	34.3000000
		AVGTMP	1087	15.1763109	2.8587251	7.7500000	24.9000000
		MINTMP	1087	10.2814167	3.4280777	0	21.2000000
		PRECIP	1087	0.4925483	1.6640632	0	15.0000000
Iraq	407	MAXTMP	407	15.3525799	4.3442547	0.6000000	28.1000000
		AVGTMP	407	9.8305897	3.5309946	-3.3000000	19.6500000
		MINTMP	407	4.3085995	4.0490526	-9.8000000	14.5000000
		PRECIP	407	1.4095823	4.2698371	0	33.0000000
Mel.	1017	MAXTMP	1017	29.5283186	1.5854793	23.2000000	39.6000000
		AVGTMP	1017	27.5400197	1.3431791	22.5000000	34.0500000
		MINTMP	1017	25.5517207	1.9847250	16.0000000	31.0000000
		PRECIP	1017	7.2794494	15.0283682	0	177.0000000
Peru	1080	MAXTMP	1080	27.2701852	3.8310835	13.6000000	34.5000000
		AVGTMP	1080	22.9249537	4.3332994	10.2000000	30.2500000
		MINTMP	1080	18.5797222	5.2228579	2.4000000	28.7000000
		PRECIP	1080	0.8442593	3.6749969	0	48.0000000
Phil.	1432	MAXTMP	1432	31.0485335	2.4138022	21.5000000	39.6000000
		AVGTMP	1432	26.6362081	1.7164769	20.0500000	32.6500000
		MINTMP	1432	22.2238827	2.0717937	10.1000000	29.0000000
		PRECIP	1432	1.7503492	7.5943071	0	133.0000000

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MONTH=3

AREA	N Obs	Variable	N	Mean	Std Dev	Minimum	Maximum
Egypt	1201	MAXTMP	1201	21.8765196	4.6233391	10.9000000	40.2000000
		AVGTMP	1201	16.9677769	3.3606563	7.5500000	29.7500000
		MINTMP	1201	12.0590341	3.5947699	1.0000000	22.9000000
		PRECIP	1201	0.4349709	3.3012537	0	99.0000000
Iraq	406	MAXTMP	406	22.0172414	4.2379413	8.8000000	34.0000000
		AVGTMP	406	16.1732759	3.3893215	6.4000000	25.3500000
		MINTMP	406	10.3293103	3.7802022	-1.3000000	21.5000000
		PRECIP	406	1.6418719	5.7049877	0	56.0000000
Mel.	1089	MAXTMP	1089	29.4635445	1.4368645	23.7000000	34.1000000
		AVGTMP	1089	27.5562443	1.3451156	22.8000000	30.8500000
		MINTMP	1089	25.6489440	2.0002255	18.1000000	30.2000000
		PRECIP	1089	8.0030303	16.7017336	0	159.9000000
Peru	1107	MAXTMP	1107	27.0124661	3.9299665	12.8000000	35.0000000
		AVGTMP	1107	22.6131888	4.4621487	4.3500000	30.2500000
		MINTMP	1107	18.2139115	5.4419596	-20.3000000	27.2000000
		PRECIP	1107	0.6550136	2.9507806	0	46.0000000
Phil.	1588	MAXTMP	1588	32.3241814	2.1637839	24.5000000	38.7000000
		AVGTMP	1588	27.7216310	1.5367376	22.0500000	32.4000000
		MINTMP	1588	23.1190806	1.8720765	13.0000000	29.3000000
		PRECIP	1588	1.2450882	6.0987366	0	132.0000000

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MONTH=4

AREA	N Obs	Variable	N	Mean	Std Dev	Minimum	Maximum
Egypt	1180	MAXTMP	1180	26.0953390	5.6746078	15.5000000	46.4000000
		AVGTMP	1180	20.6436864	3.9844524	12.0500000	36.4000000
		MINTMP	1180	15.1920339	3.8512839	3.2000000	30.0000000
		PRECIP	1180	0.0693220	0.6462060	0	16.0000000
Iraq	387	MAXTMP	387	29.7917313	5.1329459	12.5000000	39.6000000
		AVGTMP	387	22.9472868	4.5365398	9.6500000	33.7500000
		MINTMP	387	16.1028424	4.6909810	6.4000000	28.7000000
		PRECIP	387	0.3912145	1.7102632	0	13.0000000
Mel.	1052	MAXTMP	1052	29.4757605	1.3473418	24.0000000	33.1000000
		AVGTMP	1052	27.5564163	1.2840544	22.3000000	30.7000000
		MINTMP	1052	25.6370722	1.9886486	19.0000000	30.0000000
		PRECIP	1052	7.4931559	16.0218004	0	122.3000000
Peru	1119	MAXTMP	1119	25.5098302	3.3183061	14.7000000	35.0000000
		AVGTMP	1119	21.2399911	3.8110567	11.2500000	30.2000000
		MINTMP	1119	16.9701519	4.7958206	0	27.7000000
		PRECIP	1119	0.7216265	4.6781872	0	120.0000000
Phil.	1539	MAXTMP	1539	33.5557505	1.9592163	26.0000000	39.2000000
		AVGTMP	1539	28.9115335	1.3769767	24.4000000	33.7000000
		MINTMP	1539	24.2673164	1.6795693	17.9000000	30.0000000
		PRECIP	1539	1.6146199	7.5907420	0	120.0000000

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MONTH=5

AREA	N Obs	Variable	N	Mean	Std Dev	Minimum	Maximum
Egypt	1199	MAXTMP	1199	28.6394495	5.8857319	18.2000000	47.8000000
		AVGTMP	1199	23.3816931	4.2642079	13.5000000	37.4000000
		MINTMP	1199	18.1239366	3.9823110	3.2000000	29.0000000
		PRECIP	1199	0.0566305	1.1412017	0	38.0000000
Iraq	401	MAXTMP	401	35.8336658	5.2522794	20.0000000	48.3000000
		AVGTMP	401	28.1889027	4.5915828	14.7000000	39.0000000
		MINTMP	401	20.5441397	4.6995502	4.4000000	32.5000000
		PRECIP	401	0.1805486	1.2611188	0	18.0000000
Mel.	1226	MAXTMP	1226	29.4309951	1.2078796	25.0000000	32.5000000
		AVGTMP	1226	27.5821778	1.1903431	23.3500000	31.2000000
		MINTMP	1226	25.7333605	1.9155445	18.4000000	30.4000000
		PRECIP	1226	6.1539152	14.8079484	0	221.0000000
Peru	1181	MAXTMP	1181	23.8879763	3.2009598	16.2000000	34.9000000
		AVGTMP	1181	19.6074090	3.7047076	10.7000000	30.4500000
		MINTMP	1181	15.3268417	5.1365440	0	26.8000000
		PRECIP	1181	0.1913633	1.5207023	0	27.0000000
Phil.	1677	MAXTMP	1677	33.4713178	2.0396474	25.4000000	40.7000000
		AVGTMP	1677	29.2775492	1.5048891	14.7500000	34.7000000
		MINTMP	1677	25.0837806	1.8457716	-3.0000000	33.5000000
		PRECIP	1677	3.7876565	12.4883133	0	181.0000000

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MONTH=6

AREA	N Obs	Variable	N	Mean	Std Dev	Minimum	Maximum
Egypt	1143	MAXTMP	1143	31.3630796	4.9651854	22.2000000	47.8000000
		AVGTMP	1143	26.1143045	3.5979932	0.3500000	38.6000000
		MINTMP	1143	20.8655293	3.7468331	-23.3000000	33.2000000
		PRECIP	1143	0.0088364	0.1996511	0	6.0000000
Iraq	383	MAXTMP	383	40.0070496	3.7884472	29.6000000	48.0000000
		AVGTMP	383	31.8140992	3.2865559	22.5500000	39.2000000
		MINTMP	383	23.6211488	3.5564920	12.0000000	32.7000000
		PRECIP	383	0.0323760	0.3974346	0	6.8000000
Mel.	1138	MAXTMP	1138	29.0289982	1.4051805	24.9000000	35.0000000
		AVGTMP	1138	27.2273726	1.2722721	23.5500000	31.6500000
		MINTMP	1138	25.4257469	1.8655879	19.4000000	30.5000000
		PRECIP	1138	4.7212654	12.2755617	0	133.0000000
Peru	1128	MAXTMP	1128	22.6375000	2.9374828	15.0000000	32.4000000
		AVGTMP	1128	18.4252660	3.5037671	9.1000000	28.5500000
		MINTMP	1128	14.2130319	5.3227458	-1.2000000	26.4000000
		PRECIP	1128	0.1128546	0.8326967	0	14.0000000
Phil.	1568	MAXTMP	1568	32.3603954	2.1222242	24.3000000	40.0000000
		AVGTMP	1568	28.6349171	1.5311550	19.3000000	34.0000000
		MINTMP	1568	24.9094388	1.7729191	12.6000000	33.0000000
		PRECIP	1568	7.9021684	21.1149066	0	228.0000000

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MONTH=7

AREA	N Obs	Variable	N	Mean	Std Dev	Minimum	Maximum
Egypt	1198	MAXTMP	1198	32.3645242	3.8942648	25.4000000	44.2000000
		AVGTMP	1198	27.5989149	2.4695478	22.0500000	36.5500000
		MINTMP	1198	22.8333055	2.5113079	14.0000000	31.0000000
		PRECIP	1198	0.0100167	0.3466992	0	12.0000000
Iraq	407	MAXTMP	407	44.1122850	2.6040224	35.0000000	52.0000000
		AVGTMP	407	35.5599509	2.3586009	29.0000000	41.7000000
		MINTMP	407	27.0076167	3.0760742	18.2000000	34.8000000
		PRECIP	407	0	0	0	0
Mel.	1181	MAXTMP	1181	28.5456393	1.4274874	23.0000000	32.0000000
		AVGTMP	1181	26.7532176	1.2298762	22.0000000	30.6000000
		MINTMP	1181	24.9607959	1.7885736	17.9000000	29.9000000
		PRECIP	1181	4.3486029	12.6516205	0	153.0000000
Peru	1187	MAXTMP	1187	21.7722831	2.6359523	15.8000000	31.3000000
		AVGTMP	1187	17.5697557	2.9756161	9.5000000	27.0000000
		MINTMP	1187	13.3672283	5.0451566	-1.7000000	23.0000000
		PRECIP	1187	0.0380792	0.4042969	0	11.4000000
Phil.	1592	MAXTMP	1592	31.7386935	1.8277552	24.4000000	37.5000000
		AVGTMP	1592	28.1373430	1.2907561	22.2500000	32.8000000
		MINTMP	1592	24.5359925	1.5369997	16.1000000	31.5000000
		PRECIP	1592	7.4662060	19.4249252	0	212.0000000

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MONTH=8

AREA	N Obs	Variable	N	Mean	Std Dev	Minimum	Maximum
Egypt	1183	MAXTMP	1183	32.4150465	3.4291638	25.5000000	44.8000000
		AVGTMP	1183	27.7798394	2.1366428	21.3000000	37.9000000
		MINTMP	1183	23.1446323	2.4941392	10.1000000	31.0000000
		PRECIP	1183	0	0	0	0
Iraq	230	MAXTMP	230	42.5721739	2.6050018	34.8000000	48.7000000
		AVGTMP	230	34.2280435	2.3085910	27.2000000	39.6000000
		MINTMP	230	25.8839130	3.2463419	15.6000000	35.0000000
		PRECIP	230	0.0043478	0.0659380	0	1.0000000
Mel.	1109	MAXTMP	1109	28.6600541	1.4804138	24.1000000	32.4000000
		AVGTMP	1109	26.8856628	1.3497784	21.7000000	30.5000000
		MINTMP	1109	25.1112714	1.9482680	16.7000000	30.2000000
		PRECIP	1109	4.6324617	13.2170028	0	154.0000000
Peru	1197	MAXTMP	1197	21.4373434	2.4110082	15.8000000	31.2000000
		AVGTMP	1197	17.2680869	2.5824977	7.9000000	24.2500000
		MINTMP	1197	13.0988304	4.6282828	-3.4000000	21.5000000
		PRECIP	1197	0.0821220	0.8316369	0	21.0000000
Phil.	1610	MAXTMP	1610	31.5998137	2.0260961	24.2000000	38.5000000
		AVGTMP	1610	28.0539441	1.3893993	21.2500000	32.6500000
		MINTMP	1610	24.5080745	1.5644741	12.5000000	31.0000000
		PRECIP	1610	11.7159627	25.8325251	0	240.0000000

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MONTH=9

AREA	N Obs	Variable	N	Mean	Std Dev	Minimum	Maximum
Egypt	1155	MAXTMP	1155	31.0245022	3.4037517	24.7000000	43.6000000
		AVGTMP	1155	26.3871429	2.2670071	19.8500000	38.5000000
		MINTMP	1155	21.7497835	2.7616442	10.0000000	36.4000000
		PRECIP	1155	0.0122078	0.2911727	0	7.0000000
Iraq	227	MAXTMP	227	37.5211454	3.9311320	28.0000000	47.0000000
		AVGTMP	227	29.3788546	3.4072434	20.6000000	37.5000000
		MINTMP	227	21.2365639	3.9383336	9.8000000	31.0000000
		PRECIP	227	0	0	0	0
Mel.	1163	MAXTMP	1163	29.0326741	1.4069102	23.5000000	33.1000000
		AVGTMP	1163	27.1406277	1.3646407	22.7000000	31.4500000
		MINTMP	1163	25.2485813	2.1032974	17.0000000	30.5000000
		PRECIP	1163	3.9536543	12.1128533	0	180.0000000
Peru	1327	MAXTMP	1327	21.9579503	2.1890089	16.2000000	30.0000000
		AVGTMP	1327	17.7336850	2.1650573	10.7000000	23.2500000
		MINTMP	1327	13.5094197	3.9232601	0.5000000	19.3000000
		PRECIP	1327	0.1723436	1.5524163	0	34.0000000
Phil.	1743	MAXTMP	1743	31.7484223	1.8458681	23.8000000	39.5000000
		AVGTMP	1743	28.0356282	1.1909478	23.7000000	32.5000000
		MINTMP	1743	24.3228342	1.3270244	17.8000000	30.0000000
		PRECIP	1743	7.3775100	19.0762642	0	227.2000000

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MONTH=10

AREA	N Obs	Variable	N	Mean	Std Dev	Minimum	Maximum
Egypt	1209	MAXTMP	1209	28.2497932	3.3482577	18.6000000	42.7000000
		AVGTMP	1209	23.4950786	2.5534847	15.6000000	32.7000000
		MINTMP	1209	18.7403639	3.3599524	6.8000000	27.2000000
		PRECIP	1209	0.2080232	1.9112841	0	36.0000000
Iraq	238	MAXTMP	238	31.6554622	4.6317961	20.3000000	42.4000000
		AVGTMP	238	24.5506303	3.8897476	15.7000000	32.7000000
		MINTMP	238	17.4457983	4.0826435	5.4000000	25.7000000
		PRECIP	238	0.2638655	1.2379874	0	13.0000000
Mel.	1249	MAXTMP	1249	29.3578062	1.4612260	23.8000000	37.6000000
		AVGTMP	1249	27.4734187	1.3475739	21.2500000	32.1000000
		MINTMP	1249	25.5890312	2.0568366	14.0000000	30.3000000
		PRECIP	1249	4.6622898	11.8800540	0	133.0000000
Peru	1365	MAXTMP	1365	22.6530403	2.0669406	14.2000000	29.0000000
		AVGTMP	1365	18.5406960	2.3114771	9.0000000	24.0500000
		MINTMP	1365	14.4283516	3.7908356	1.0000000	20.3000000
		PRECIP	1365	0.5699634	2.9778986	0	43.0000000
Phil.	1782	MAXTMP	1782	31.6547699	1.9670866	23.5000000	38.2000000
		AVGTMP	1782	27.8273008	1.2310596	23.2500000	32.0000000
		MINTMP	1782	23.9998316	1.3867687	16.6000000	29.5000000
		PRECIP	1782	5.6112795	14.5114380	0	146.0000000

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MONTH=11

AREA	N Obs	Variable	N	Mean	Std Dev	Minimum	Maximum
Egypt	1150	MAXTMP	1150	24.5934783	3.2217712	14.6000000	36.6000000
		AVGTMP	1150	19.4523913	2.7208869	10.9000000	29.2500000
		MINTMP	1150	14.3113043	3.8631973	1.0000000	24.6000000
		PRECIP	1150	0.3343478	2.1791945	0	33.0000000
Iraq	305	MAXTMP	305	21.0495082	4.7398446	9.7000000	32.0000000
		AVGTMP	305	15.5709836	4.2111462	4.7000000	25.5500000
		MINTMP	305	10.0924590	4.8670187	-2.6000000	21.9000000
		PRECIP	305	1.4272131	4.3769522	0	40.0000000
Mel.	1185	MAXTMP	1185	29.7229536	1.3419793	24.0000000	34.4000000
		AVGTMP	1185	27.7342616	1.2818720	23.5500000	31.8000000
		MINTMP	1185	25.7455696	2.0848632	20.5000000	31.6000000
		PRECIP	1185	5.4809283	13.2620696	0	132.0000000
Peru	1275	MAXTMP	1275	23.9007843	2.1712441	10.8000000	33.0000000
		AVGTMP	1275	19.5221961	2.7754463	7.0500000	26.7500000
		MINTMP	1275	15.1436078	4.4485772	-4.2000000	24.1000000
		PRECIP	1275	0.4204706	3.2807387	0	94.0000000
Phil.	1732	MAXTMP	1732	31.3500577	2.0624774	23.3000000	37.8000000
		AVGTMP	1732	27.4923499	1.3377072	22.5000000	31.4500000
		MINTMP	1732	23.6346420	1.5641716	16.1000000	30.5000000
		PRECIP	1732	3.2639723	10.0829446	0	202.5000000

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MONTH=12

AREA	N Obs	Variable	N	Mean	Std Dev	Minimum	Maximum
Egypt	1194	MAXTMP	1194	20.6167504	3.5369875	12.0000000	32.9000000
		AVGTMP	1194	15.9117253	2.8028090	8.7000000	24.9000000
		MINTMP	1194	11.2067002	3.5833164	-0.9000000	22.8000000
		PRECIP	1194	0.5586265	2.5556532	0	29.0000000
Iraq	445	MAXTMP	445	15.1653933	4.5306332	2.8000000	25.4000000
		AVGTMP	445	10.3557303	3.8127462	0.4000000	22.4000000
		MINTMP	445	5.5460674	4.1220473	-4.4000000	22.0000000
		PRECIP	445	1.5523596	5.6579471	0	78.0000000
Mel.	1186	MAXTMP	1186	29.7637437	1.5887529	23.5000000	42.1000000
		AVGTMP	1186	27.7250000	1.3440747	23.1000000	33.3000000
		MINTMP	1186	25.6862563	2.0427015	18.3000000	30.9000000
		PRECIP	1186	6.7459528	14.3659697	0	132.0000000
Peru	1291	MAXTMP	1291	25.5725019	2.6913433	15.5000000	34.0000000
		AVGTMP	1291	21.1511619	3.5106011	8.9500000	28.7500000
		MINTMP	1291	16.7298218	4.9419970	-4.6000000	26.0000000
		PRECIP	1291	0.3451588	1.7706735	0	29.0000000
Phil.	1760	MAXTMP	1760	30.7688636	2.1253089	22.0000000	40.2000000
		AVGTMP	1760	26.5901420	1.6194466	20.2000000	31.1000000
		MINTMP	1760	22.4114205	2.2236161	11.5000000	29.5000000
		PRECIP	1760	1.7792045	6.6775373	0	121.8000000

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