2008

Anthropometric Variation in California: A Study of Native American Populations

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ANTHROPOMETRIC VARIATION IN CALIFORNIA:

A STUDY OF NATIVE AMERICAN POPULATIONS

By

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Bachelor of Arts, Baylor University, Waco, TX, 2005

Thesis

presented in partial fulfillment of the requirements
for the degree of

Master of Arts
in Anthropology, Forensic Anthropology

The University of Montana
Missoula, MT

Spring 2008

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Mahoney, Catherine, M.A., May 2008 Anthropology

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Physical anthropologists study the patterns of human morphology to observe the influence of genetics and environment on cranial form. The following study compares cephalic and nasal index means from four Native American populations using modern statistical methods, including one-way ANOVA tests and Games-Howell comparison tests. The individuals used were of only Native American ancestry, over the age of seventeen when the data was collected, and were divided into male and female samples. The climatic conditions of each of the regions are compared to examine the relationship between the mean cranial and nasal indices and the environments in which the populations lived. Previous research suggests that larger cephalic indices should be found in populations from colder climates and larger nasal indices should be found in populations from warmer climates. Some cases in which a significant difference in means was found between populations it followed the pattern predicted from the environmental differences, though one population (the Miwok) provided an exception.

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CHAPTER 1: INDRODUCTION

Anthropometric and Osteometric Studies

Anthropometric variation has been a point of study not only in physical anthropology, but other fields such as genetics, anatomy, dentistry, and for industrial purposes (Roberts, 1956; Kohn, 1991). Physical anthropologists study the measurements taken from both living individuals and human skeletal remains to evaluate traits of normal development as well as patterns of development. This research examines the morphology of living individuals from different cultural groups and environmental conditions to determine if any significant differences are present.

Past research often evaluated differences in physical development as a way to determine and categorize separate “races” (Crawfurd, 1868; Boas, 1899; Radosaljevich, 1911; Davies, 1929, 1932; Howells, 1955; Hunt, 1959; Cavalli-Sforza, 1972; Allen, 1989; D’Agostino, 2002; Gravelee et al., 2003). It has been found in modern research that roughly 85-90% of human variation occurs within a population and 10-15% occurs between populations (Relethford, 1998). This demonstrates the effects that genetic drift and gene flow have on populations (Relethford, 1998). Genetic drift occurs within an isolated population and decreases heterozygosity, while gene flow is due to new genes being introduced between populations (Cavalli-Sforza, 1972; Relethford, 1998). Other research in human genetic variation has found that morphology is the result of multifactorial inheritance and these traits are subject to continuous variation (Kohn, 1991). An expressed trait, or phenotype, is the sum of both the genotypic value and environmental factors (Kohn, 1991). Heritability is a technique for estimating inheritance of a specific trait within a particular population and is commonly used when comparing populations (Kohn, 1991; Gravlee et al., 2003b).

One of the largest data sets of anthropometric data comes from Boas (1912; 1928; 1940) in which Boas analyzed information and measurements from European-born immigrants and their American-born children (Sparks and Jantz, 2002). Boas (1912; 1940) found that a change in environmental conditions of the mother as well as the child's exposure to the environment affects cranial morphology (Gravlee et al., 2003b). This data set has recently been reanalyzed using modern techniques to evaluate the original results and the conclusions about the plasticity of cranial form and the profound influence that changes in environment may have on these features during growth and development (Boas, 1912; Holden, 2002; Holloway, 2002; Sparks and Jantz, 2002, 2003; Gravlee et al., 2003a, b).

Using the same Boas data (1928), Sparks and Jantz (2002) estimated narrow sense heritability as well as perform t-tests, an analysis of variance, and a regression analysis to study the statistical validity of Boas' (1912; 1940) conclusions. With these tests, it was found that the primary source of cranial variation was due to genetics and not largely influenced by environmental conditions (Sparks and Jantz, 2002). To investigate further, Gravlee et al. (2003a) also reanalyzed the original findings by Boas (1912; 1940) using modern statistical methods. Gravlee et al. (2003a) used analysis of covariance, analysis of variance, and regression coefficients with the cephalic index to compare to the original findings by Boas (1912, 1940). The results are consistent with the original hypothesis and the modern statistical methods allow for more detailed analyses (Gravlee et al., 2003).

Gravlee et al. (2003a, b) critiqued and expanded upon the results reached by Sparks and Jantz (2002) stating that their results largely support the original findings by Boas (1912, 1940). It was argued that Sparks and Jantz (2002) initially misinterpreted the basis for the influence of environmental conditions and their results were misleading. Sparks and Jantz (2003) reevaluated and defended their original findings and further discussed the impact of the analyses of the immigrant data in the physical anthropology community.

There have been a large number of other studies using anthropometric data to study the effects of genetics, environment, and demographics on human variation (Spielman et al., 1979; Williams et al., 1979; Sunderland et al., 1981; Majumder et al., 1990; Kohn, 1991). Williams et al. (1979) reanalyzed anthropometric records of Welshmen and compared them with two more recent samples using multivariate techniques. Using facial and body measurements of adult males, the discriminant function analysis revealed important associations between geographical regions and populations while isolating those populations that were significantly different (Williams et al., 1979). Another anthropometric study using multivariate discriminant function analysis was performed by Sunderland et al. (1981) using data collected from six regions within Wales and examining males and females separately. Similar results were found in both the male and female analyses creating two larger groups: eastern counties with a more English influence; and western counties with a Welch influence (Sunderland et al., 1981).

The Yanomama population has been a focus of anthropological research resulting in extensive data collection due to their distinctive geographical isolation (Spielman et al., 1972; Ward, 1972; Spielman, 1973; Spielman et al., 1974; Ward et al., 1975; Spielman et al., 1979). In one study, Spielman et al. (1979) provide a multidisciplinary study of the relationship between the Yanomama and the Guaymi concerning genetics, anthropometrics, and linguistics. The anthropometric data supports the genetic results that the two tribes are unlikely to be closely related (Spielman et al., 1979). In another study with the Yanomama, researchers compared anthropometric data from nineteen villages to find similarities in shape and size (Spielman, 1973). The results show a stronger morphological similarity between men and women from the same villages than between the populations (Spielman, 1973).

Environmental Effects on the Cephalic and Nasal Index

Environmental factors that may affect morphology include climate, nutrition, and cultural influences (Boas, 1912, 1940; Kohn, 1991; Gravlee et al., 2003b; Mielke et al., 2005). Malnutrition can slow the growth process which can cause physical and mental development problems (Mielke et al., 2005). High altitude has been found to mainly affect the measurements of the chest cavity and body size resulting in a larger chest area but smaller body size (Mielke et al., 2005). Studies have found that cranial shapes and sizes are influenced by climate including temperature and humidity (Mielke et al., 2005). It is typical for individuals in cold climates to have a larger cephalic index than those in hot climates (Mielke et al., 2005). The nasal index is significantly affected by climate as well: populations in hot climates tend to have larger nasal index measures than those in cold climates; and populations in wet climates have a broader nasal index than those in dry areas (Thomson and Buxton, 1923; Davies, 1929, 1932; Mielke et al., 2005). This variation is generally attributed to the function of the nasal organ regulating the temperature and moisture of the air before it comes in contact with the delicate lung tissues (Thomson and Buxton, 1923; Davies, 1929). These results tend to be generalizations because morphological variation still occurs within areas since morphology is the result of all environmental effects and genetic factors.

Foundations of this Study

From the above discussion it is clear that statistical analyses performed during the early 20th century can benefit from reanalysis using modern methods and assumptions. It is important to continue interdisciplinary research to reevaluate results with available methods and with the growing knowledge of human biology. Understanding modern human morphology and variation aids in our understanding of the evolutionary past and what the future may hold. To develop upon the current research and understandings of anthropometric variation, the records compiled by Gifford (1926), which included measurements of living individuals from a variety of California Native American tribes, are herein analyzed using modern statistical methods.

The following analyses evaluate similarities between Native American tribes in four regions of California using the measurements from individuals living in these areas during the early twentieth century. While Gifford's (1926) original research with this data focused on means of the individual tribes, this research examines significant differences between regions using more modern statistical analyses. With these analyses I will explore the hypothesis that significant difference of the cephalic and nasal index means are present between the populations as well as if these differences could be explained by climatic conditions.

CHAPER 2: MATERIALS AND METHODS

The raw data used in this research originates from the published records of Gifford (1926), from which 31 variables taken from a total of 682 Native Americans living throughout California in the early twentieth century were used to create a database for statistical analyses. Measurements from these individuals were collected over the course of twenty years by members of the department of anthropology at the University of California in Berkeley (Gifford, 1926). The tools for obtaining these measurements at this time would have included spreading calipers for large round measures, sliding calipers for short distance measures, an anthropometer for the various height measures, and a hand-dynamometer which measures the strength of each hand in kilograms (Moore and Sturm, 1952; Hoyme, 1953).

The variables and information collected about these individuals include: case ID number; tribe and geographical association; sex; age; stature; height of shoulder; height of middle finger from ground; stretch of arms; height sitting; width of shoulders; length of forearm (elbow to tip of middle finger); length of head; breadth of head; length of face from the hair line; length of face from nasion; breadth of face; length of nose; breadth of nose; length of ear; breadth of ear; reach index of arms; cephalic index; facial index using nasion; nasal index; and ear index (Gifford, 1926). Also included is the color of exposed and unexposed skin according to Broca’s scale, ancestry including Native American and non-Native American associations, and kilograms squeezed on a steel dynamometer with each hand (Gifford, 1926). The measurements were manually entered into the computer program SPSS 15.0 and were checked for errors after each tribe was entered. Other variables used for this analysis were the cephalic index and nasal index. The cephalic index is the ratio of an individual's head breadth divided by head length, then multiplied by 100 (Mielke et al., 2005). The nasal index is the ratio of the nose breadth divided by the nose length, then multiplied by 100 (Mielke et al., 2005).

Each tribe had a geographical area within a particular region of associated tribes; these areas can be found in Figure 1. The original coding of each region was kept for this study and is found in Table 1, but not all the regions and tribes are represented in the data set. The following analyses utilize information from individuals descending from two Northern California populations, Athabascan and Yurok, as well as two Central California populations, Miwok and Shoshonean. The regions of these populations are highlighted in Figure 1. Subjects with only Native American ancestry were included and from this sample each sex was analyzed separately using a total of 77 male and 79 female individuals. Only individuals over the age of seventeen years when measured were included, with the assumption that puberty had already occurred by this age. The significance level was set at .05, meaning that if the significance is less than .05, then the null hypothesis of no difference between populations is rejected and I will conclude that there is a significant difference present between the populations (Landau and Everitt, 2004).

Each of the regions studied are divided among a number of associated Native American tribes. The Athabascan area includes the Hupa, Tolowa, Chilula, Whilkut, Mattole, Nongatl, Lassik, Sinkyone, Wailaki, Kato, and Rogue River tribes (Gifford, 1926). The tribes in the Yurok area include the Yurok, Coast Yurok, and Wiyot (Gifford, 1926). The Miwok area consists of the Coast, Lake, Plains, Northern, Central, and Southern Miwok tribes (Gifford, 1926). The fourth area covers the largest land area across Central California and a piece of land in Northeastern California (Gifford, 1926). The Shoshonean region includes the Northern Paiute, Eastern Mono, Western Mono, Koso, Chemehuevi, Kawaiisu, Tϋbatulabal, Kitanemuk, Alliklik, Vanyume, Serrano, Fernandefio, Gabrielino, Nicoleno, Juaneno, Liseno, Cupeno, Pass Cahuilla, Mountain Cahuilla, and Desert Cahuilla tribes (Gifford, 1926).

The computer program SPSS 15.0 was used in this research to create a database containing the raw data from Gifford (1926) and run the analyses. This program was chosen because it is a comprehensive system for data analysis and it automatically excludes individuals from an analysis if they do not meet the criteria or if any of the chosen variables are missing from their record (Landau and Everitt, 2004). One-way analysis of variance (ANOVA) tests were performed on the male and female samples as well as Games-Howell multiple comparison tests to further examine differences between the populations. The ANOVA test identifies significant differences between groups that have had different treatment along with the contribution of each group to the total variation (Landau and Everitt, 2004). The Games-Howell test is used where the sample sizes and variances are unequal and there is a small sample size (Everitt, 2001; Garson, 2008). Also included with these results were the means for each sample which were used to compare the populations. The tables produced from these tests were exported into a word document for further analysis.

Table 1: Geographical Coding of Regions

Geographical Zone	Code
Athabascan	1
Yurok	2
Miwok	18
Shoshonean	21

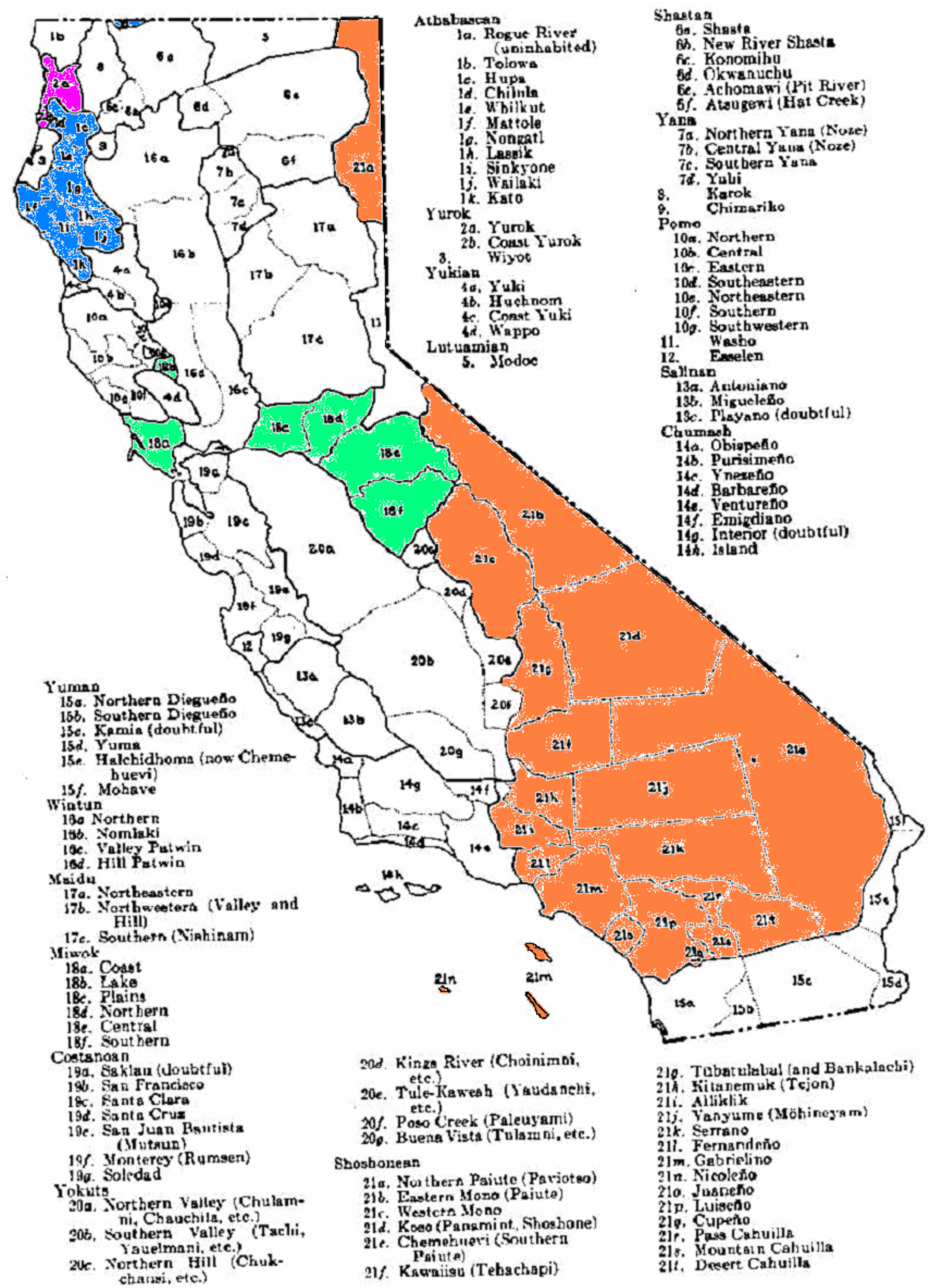
Table 2: Individuals from Each Region – Males

Area	*N*
1	19
2	20
18	19
21	19
Total	77

Table 3: Individuals from Each Region – Females

Area	*N*
1	21
2	16
18	14
21	28
Total	79

Figure 1: Original Map of Regions (Gifford, 1926)



CHAPTER 3: RESULTS

The geographical coding for each region can be found in Table 1 and the corresponding map in Figure 1. Tables 2 and 3 show the total number of individuals, *N*, from each sample and each population. The results from the one-way ANOVA tests using the male sample are found in Table 4, and the ANOVA results from the female sample are in Table 5. Table 6 has the results from the Games-Howell comparison tests for the male sample, and Table 7 has the results from the female sample. The cephalic index means of the male samples used in the analyses are found in Table 8 and their nasal index means are found in Table 9. Table 10 has the cephalic index means, and Table 11 has the nasal index means for the female samples.

Table 4: ANOVA Results for CI and NI – Males

		Sum of Squares	Df	Mean Square	F	Sig.
CI	Between Groups	1005.318	3	335.106	27.431	.000
	Within Groups	891.797	73	12.216		
	Total	1897.115	76			
NI	Between Groups	478.436	3	159.479	3.350	.024
	Within Groups	3475.554	73	47.610		
	Total	3953.990	76			

Table 5: ANOVA Results for CI and NI – Females

		Sum of Squares	df	Mean Square	F	Sig.
CI	Between Groups	782.895	3	260.965	15.816	.000
	Within Groups	1237.494	75	16.500		
	Total	2020.388	78			
NI	Between Groups	1002.684	3	334.228	5.551	.002
	Within Groups	4515.565	75	60.208		
	Total	5518.249	78			

Table 6: Games-Howell Comparison Tests – Males

Dependent Variable	(I) Area	(J) Area	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Upper Bound	Lower Bound
CI	1	2	-1.9932	1.0825	.271	-4.909	.922
		18	-7.0684(*)	1.0722	.000	-9.960	-4.177
		21	2.9053	1.2527	.113	-.472	6.282
	2	1	1.9932	1.0825	.271	-.922	4.909
		18	-5.0753(*)	.9913	.000	-7.741	-2.409
		21	4.8984(*)	1.1841	.001	1.699	8.098
	18	1	7.0684(*)	1.0722	.000	4.177	9.960
		2	5.0753(*)	.9913	.000	2.409	7.741
		21	9.9737(*)	1.1747	.000	6.796	13.152
	21	1	-2.9053	1.2527	.113	-6.282	.472
		2	-4.8984(*)	1.1841	.001	-8.098	-1.699
		18	-9.9737(*)	1.1747	.000	-13.152	-6.796
NI	1	2	-3.0392	2.2141	.524	-8.995	2.916
		18	.5263	2.1650	.995	-5.305	6.357
		21	3.9474	2.2226	.301	-2.039	9.934
	2	1	3.0392	2.2141	.524	-2.916	8.995
		18	3.5655	2.2218	.388	-2.411	9.542
		21	6.9866(*)	2.2779	.020	.859	13.114
	18	1	-.5263	2.1650	.995	-6.357	5.305
		2	-3.5655	2.2218	.388	-9.542	2.411
		21	3.4211	2.2303	.428	-2.586	9.428
	21	1	-3.9474	2.2226	.301	-9.934	2.039
		2	-6.9866(*)	2.2779	.020	-13.114	-.859
		18	-3.4211	2.2303	.428	-9.428	2.586

* The mean difference is significant at the .05 level.

Table 7: Games-Howell Comparison Tests – Females

Dependent Variable	(I) Area	(J) Area	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Upper Bound	Lower Bound
CI	1	2	-2.6741	1.0975	.089	-5.636	.288
		18	-8.7500(*)	1.1289	.000	-11.814	-5.686
		21	-.5357	1.2500	.973	-3.866	2.794
	2	1	2.6741	1.0975	.089	-.288	5.636
		18	-6.0759(*)	1.1191	.000	-9.134	-3.017
		21	2.1384	1.2412	.325	-1.182	5.459
	18	1	8.7500(*)	1.1289	.000	5.686	11.814
		2	6.0759(*)	1.1191	.000	3.017	9.134
		21	8.2143(*)	1.2691	.000	4.808	11.621
	21	1	.5357	1.2500	.973	-2.794	3.866
		2	-2.1384	1.2412	.325	-5.459	1.182
		18	-8.2143(*)	1.2691	.000	-11.621	-4.808
NI	1	2	-6.0503	3.0134	.212	-14.329	2.228
		18	3.6524	2.2079	.364	-2.334	9.639
		21	2.9774	2.0889	.491	-2.601	8.556
	2	1	6.0503	3.0134	.212	-2.228	14.329
		18	9.7027(*)	3.0124	.018	1.399	18.006
		21	9.0277(*)	2.9263	.024	.951	17.104
	18	1	-3.6524	2.2079	.364	-9.639	2.334
		2	-9.7027(*)	3.0124	.018	-18.006	-1.399
		21	-.6750	2.0875	.988	-6.330	4.980
	21	1	-2.9774	2.0889	.491	-8.556	2.601
		2	-9.0277(*)	2.9263	.024	-17.104	-.951
		18	.6750	2.0875	.988	-4.980	6.330

* The mean difference is significant at the .05 level.

Table 8: Means of Cephalic Index – Males

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	19	81.237	3.5662	.8181	79.518	82.956	70.9	86.2
2	20	83.230	3.1698	.7088	81.746	84.714	77.7	90.3
18	19	88.305	3.0206	.6930	86.849	89.761	82.1	94.3
21	19	78.332	4.1348	.9486	76.339	80.324	70.7	84.2
Total	77	82.782	4.9962	.5694	81.648	83.916	70.7	94.3

Table 9: Means of Nasal Index – Males

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	19	80.416	6.6485	1.5253	77.211	83.620	67.2	91.2
2	20	83.455	7.1773	1.6049	80.096	86.814	67.9	102.2
18	19	79.889	6.6974	1.5365	76.661	83.118	70.5	93.9
21	19	76.468	7.0465	1.6166	73.072	79.865	67.2	92.5
Total	77	80.101	7.2129	.8220	78.464	81.738	67.2	102.2

Table 10: Means of Cephalic Index – Females

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	21	79.757	3.5884	.7831	78.124	81.391	73.7	85.8
2	16	82.431	3.0757	.7689	80.792	84.070	77.3	87.9
18	14	88.507	3.0424	.8131	86.751	90.264	83.3	93.0
21	28	80.293	5.1559	.9744	78.294	82.292	73.1	92.9
Total	79	82.039	5.0894	.5726	80.899	83.179	73.1	93.0

Table 11: Means of Nasal Index – Females

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	21	81.481	7.1589	1.5622	78.222	84.740	66.7	98.0
2	16	87.531	10.3075	2.5769	82.039	93.024	69.1	102.3
18	14	77.829	5.8380	1.5603	74.458	81.199	68.9	87.4
21	28	78.504	7.3380	1.3868	75.658	81.349	64.9	91.7
Total	79	81.004	8.4111	.9463	79.120	82.888	64.9	102.3

CHAPTER 4: DISCUSSION

Males:

The cephalic and nasal indices from 77 adult males from four Native American geographic regions were analyzed with one-way ANOVA tests and by a Games-Howell comparison test for population to population significance. The one-way ANOVA test of the cephalic index measures of the male samples revealed a significance of less than .001, as seen in Table 4, indicating that the population's regions had an effect on the measurement of the cephalic index. The nasal index was also determined to have a significant relationship with the geographic regions with a significance of .024.

The Games-Howell comparison test reveals significant differences between the individual populations with respect to a particular variable. The results of the cephalic index Games-Howell comparison test of the male samples, found in Table 6, show several significant differences in variances between the populations. It was revealed that the sample population in the Miwok region is significantly different from each of the other three regions with significances less than .001. The other significantly different relationship that occurred using the cephalic index variable was between the Yurok region and the Shoshonean region. The Games-Howell test using the nasal index on the male samples revealed only one significant relationship: the Yurok and Shoshonean regions were found to be significantly different at .020.

The population that had the highest cephalic index mean for this sample was the Miwok population with 88.3%. The lowest mean was 78.3% for the Shoshonean population. The largest difference between nasal index means occurs between the Shoshonean population with 76.5%, and the Yurok population with 83.5%.

Females:

A total of 79 adult females from the same four geographical regions were also analyzed with one-way ANOVA tests and Games-Howell comparison tests using the cephalic and nasal index variables. The one-way ANOVA test results show the cephalic index test had a significance less than .001 and the nasal index significance was found to be .002.

A multiple comparison test was performed to study significantly different relationships between these populations in relation to the cephalic and nasal indices. This Games-Howell test using the cephalic index revealed similar results as the one performed on the male samples. The Miwok population was determined to be significantly different than the other three populations, each with a significance of less than .001. The results from the nasal index Games-Howell test showed only two significantly different relationships; the Yurok region was significantly different from the Miwok and the Shoshonean regions.

Using the female sample, the Miwok population stood out with the largest cephalic index mean, 88.5%. The Athabascan and Shoshonean populations had similar cephalic index means with 79.7% and 80.0% respectively. The population with the largest nasal index mean is the Yurok population with 87.5%. The Miwok population had the smallest nasal index with 77.8%, which was similar to the Shoshonean population with 78.5%.

Each of the cephalic index means tables show that the Miwok population has a higher value than the other populations, indicating that these individuals have broader heads than those from the other populations. The ANOVA and Games-Howell tests confirm that this difference is significant. The nasal index means from both the male and female samples reveal that the Miwok population has the lowest mean and the Yurok population has the highest. This indicates that the Miwok population has narrow noses, while individuals of the Yurok population have broader noses.

The results show that significant differences occur between the populations for both the cephalic and nasal indices. The Miwok population stood out significantly from each population in both the male and female samples with regard to the cephalic index. The tests using the nasal index means showed that the Yurok population has a significant difference from the Shoshonean population in the male sample and the Miwok population in the female sample. To explore these differences more, the environmental conditions of the populations are examined.

The environments of these areas differ in temperature, humidity, elevation, and seasonality (Hittell, 1863; de Blij, 2005). The Athabascan and Yurok tribes are located near one another and experience the same cool and humid coastal environment at relatively low elevation and with relatively less seasonality (Hittell, 1863; Gifford, 1926; de Blij, 2005). A cool, humid climate would result in larger cephalic index values as well as higher nasal index values (Mielke et al., 2005). The Miwok region is located across Central California, spanning from the coast toward the east side of the state (Gifford, 1926). The individuals used in this data set mainly come from the Central Valley area which experiences seasonal changes from cool and damp winters to hot and dry summers (Hittell, 1863; de Blij, 2005). The changes in temperature and humidity throughout the year might affect these individuals differently than the general correlation between cephalic and nasal indices with climate. The Shoshonean region spans most of the eastern border of California, but the tribes included in this analysis come mostly from the central and northern border regions, inhabiting a desert environment that is very hot and dry (Gifford, 1926; de Blij, 2005). The hot and dry climate is reflected in lower cephalic and nasal index values, which are present in each sample. This area is also relatively high in elevation, ranging from about 1800 to about 9000 feet above sea level (de Blij, 2005). After reviewing the differences in climatic conditions, we could expect to see the greatest differences between the Northern California populations and the Shoshonean population.

Due to their similar environment, it is not surprising that no significant differences between the peoples of the Athabascan and Yurok regions were found.

Although part of the Shoshonean region is near the Miwok territory, they experience different climates due to a rain shadow effect caused by the presence of mountains. The east side of the mountains is subject to a drier climate year round, while the coastal region receives high rainfall (Hittell, 1863; de Blij, 2005). Despite the difference in climate, the Shoshonean population did not differ from the Miwok or the Athabascan populations in nasal index. Significant differences exist in mean nasal index with males and females from the Yurok region. This difference follows the expected pattern of larger nasal indices in dryer climates.

They were also significantly different from the Yurok and Miwok, but not the Athabascan, populations with regard to mean cephalic index. This difference is also in the direction expected from consideration of the climate differences. The Shoshoneans have distinctively small cephalic indices compared to the Yurok and Miwok, reflecting an adaptation to their cooler environment.

Although the Miwok population experiences hot and cold as well as dry and humid times of the year, there was significant difference between the nasal index means of the Miwok and Yurok populations in the female sample. The nasal index of the Miwok females is smaller than that of the Yurok females, suggesting an adaptation to a more humid climate. This does not correspond with the seasonally dry climate of the Central Valley region and either reflects a recent migration of the Miwok from a much more humid region or suggests that the climatic correlations of this index are not valid for the Miwok.

The cephalic index of the Miwok showed a significant difference between them and all of the other populations for both the male and female samples. The Miwok have a distinctively large cephalic index, which would suggest adaptation to a distinctively cool climate. Again, either the climatic implications of the cephalic index are not valid for the Miwok, or they are more recent immigrants from a cooler climatic region.

To examine potential migration patterns of the Miwok, the language family is examined. The Miwok population is associated with the Penutian language family, which spans the across Central California to the coast as well as north through Central Oregon and the Oregon coastline (Goddard, 1996). This could indicate that the Miwok population was once located along the coast in a cool, humid climate, before migrating to the Central California area.

The demographics and social conditions of these populations at this time may have also been a contributing factor to their morphology (Kohn, 1991). During the early twentieth century, California was becoming more and more populated by individuals of European and Asian descent (Nelson, 1978; Jurmain and Rawls, 1986). Native American communities were segregated from the booming economy and so their living conditions may have been less than optimal, causing poor nutrition (Nelson, 1978; Jurmain and Rawls, 1986). At this time women could still be traded as brides in exchange for products or money between tribes (Lowie, 1924; Nelson, 1978; Jurmain and Rawls, 1986). This would affect the morphology of their offspring not only due to gene flow, but also the change in environmental conditions the mother is exposed to (Boas, 1912, 1940; Gravelee et al., 2003b).

Several steps were taken to minimize the effect of these factors on the analysis. The samples were separated into ancestry, age and sex groups. Only those individuals that were recorded as having only Native American ancestry were selected for analysis to limit the potential genetic influence from immigrants to the United States. There could still be admixture from other Native American populations within a region. The ages of the individuals were also limited to older than seventeen years at the time the measurements were recorded. This age range assumes that puberty has taken place for most individuals and the cranial form is mostly set by that time (Mielke et al., 2005). Males and females were also separated to eliminate any differences that may occur between the sexes (Parsons, 1922; Thomson and Buxton, 1923; Wallis and Wallis, 1946).

Even though these selections were made, some problems may still occur with the data, including small and unequal sample sizes. After these limitations were imposed on each population, the sample sizes were reduced to an average of about 19 males and 19 females per population. This is a relatively small sample size when compared to the number of individuals who made up the original population, but was still adequate to reveal some significant differences. Larger sample sizes may reveal additional significant differences that were not revealed using the small samples. The sample sizes from each population were unequal, but this was mitigated by using the Games-Howell comparison test, which is used for comparing small samples of unequal size and variance (Everitt, 2001; Garson, 2008). Also, all of the tribes associated with a particular region were included in that region's sample. This was done because in this data set it was found that most of the individuals from this sampling who had multiple Native American tribes in their ancestry were related to another tribe in the same region (Gifford, 1926).

At the time this data was collected, the field of anthropology was attempting to standardize the locations and tools used in anthropometry (Garson, 1887; Boas and Boas, 1913; Hoyme, 1953). It is recorded that multiple individuals were responsible for taking the measurements, but it is assumed that they used standardized locations and tools for their project (Gifford, 1926). It was also believed that the individuals who recorded the measurements were trustworthy and that the records are accurate. Also, it is assumed that information on all the individuals from an area was recorded within a constrained time frame, limiting the possible effect of changes in the environmental conditions over the time period in which the data was collected.

Future analysis of this data could utilize other records of Native Americans at this time or from current populations. Another study of interest might be to analyze the Native American populations, those with some non-Native American ancestry, and those with European ancestry. Using another program such as RMET, or a Relethford-Blangero analysis may also reveal relationships between the populations. It is important to continue examining variation within and between populations to expand our overall understanding of human variation.

CHAPTER 5: CONCLUSION

The one-way ANOVA analyses for the male and female samples confirmed that significant differences occur between the populations' means for both the cephalic and nasal indices. Further analysis about the populations compared significance between each population and found that the Miwok region stood out from the others with regard to the cephalic index. The nasal index tests showed that the Yurok population was also significantly different from the Shoshonean and Miwok populations. The populations that displayed significant differences were found to have different climatic conditions, which could explain some of the variation, but the differences are probably due to a combination of genetic and environmental factors.

In most cases, the observed differences followed the pattern expected from the climatic conditions of the region where each group lived at the time the data were collected, with larger cephalic indices reflecting a cooler climate and larger nasal indices reflecting a dryer climate. The exception was the Miwok, who live in a seasonal, but generally hot and dry region, and have a large mean cephalic index and a relatively small nasal index. Either these indices are not reflecting climate well for the Miwok, or they are more recent immigrants from a cooler and more humid region. Since some Miwok also live on the California Coast, north of San Francisco Bay, it is possible that this population was originally adapted for the cooler, more humid climate of that area and expanded their range into the Central Valley later in time.

Physical anthropology studies variation among populations to develop a better understanding of what influences may affect human morphology. While this analysis focuses on populations with Native American ancestry using the cephalic and nasal indices, future research may be able to use this data set with other populations as well as utilizing other variables. It is important to continue this interdisciplinary research to expand upon our current knowledge and understanding of human morphology and the factors that influence it.

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APPENDIX A: Codebook for Data Set from Gifford (1926)

Individual	Case ID number
Tribe	Tribe individual is associated with
Tribal#	Number associated with tribe
Area	Region associated with tribe; see Geographic Zone Table
Sex	Sex: Male = 0; Female = 1
Age	Age in years
Quantum	Recorded ancestry: 1 = full Native American; 2 = half white; 3 = one quarter white; 4 = three quarters white; 5 = other
Stature	Individual's stature (cm)
HSh	Height of shoulder (cm)
HMF	Height of middle finger from ground (cm)
Stretch	Stretch of arms (cm)
HS	Height sitting (cm)
WSh	Width of shoulders (cm)
LF	Length of forearm (elbow to tip of middle finger) (cm)
LH	Head length (cm)
BH	Head breadth (cm)
LFH	Length of face (hair line) (cm)
LFN	Length of face (nasion) (cm)
BF	Breadth of face (cm)
LN	Length of nose (cm)
BN	Breadth of nose (cm)

LE	Length of ear(cm)
BE	Breadth of ear (cm)
RI	Index of reach or stretch of arms (cm)
CI	Cephalic index
FI	Facial index (nasion)
NI	Nasal index
EI	Ear index
U	Skin color of unexposed skin according to Broca's scale
E	Color of exposed skin according to Broca's scale
SqR	Kilograms squeezed on steel dynameter with Right hand
SqL	Kilograms squeezed on steel dynameter with Left hand

APPENDIX B: Geographical Zones for Each Region, from Gifford (1926)

Geographical Zone	**Code**	**Geographical Zone**	**Code**
Athabascan	1	Yuman*	15
Yurok	2	Wintun	16
Wiyot	3	Maidu	17
Yukian	4	Miwok	18
Lutuamian	5	Costanoan*	19
Shastan	6	Yokuts	20
Yana	7	Shoshonean	21
Karok	8	Warm Springs (OR)	22
Chimariko	9	Cocopa (Lower Cailifornia)	23
Pomo	10	Northwest Mixed Tribes	24
Washo	11	Round Valley Mixed Tribes	25
Esselen*	12	Northeast Mixed Tribes	26
Salinan	13	Miscellaneous Hybrids	27
Chumash	14		

*No data provided for this region