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Patterns of Sexual Dimorphism in North American Indian Groups

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To the Graduate Council:

I am submitting herewith a thesis written by Cathi Lee Sullivan entitled "Patterns of Sexual Dimorphism in North American Indian Groups." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Anthropology.

Richard L. Jantz, Major Professor

We have read this thesis and recommend its acceptance:

William M. Bass, Lyle W. Konigsberg

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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

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CWMinkel

Associate Vice Chancellor
and Dean of The Graduate School

PATTERNS OF SEXUAL DIMORPHISM IN NORTH AMERICAN INDIAN GROUPS

A Thesis Presented for the
Master of Arts Degree
The University of Tennessee, Knoxville

Cathi Lee Sullivan
December 1995

DEDICATION

For my Grandfather

Albert Lee Butler

Daddy-o, this is for you.

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ABSTRACT

This study examines patterns of sexual dimorphism in 26 North American Indian and Siberian groups. Past research on sexual dimorphism has looked into possible causitive factors such as nutritional status, settlement type, marriage systems, sexual division of labor, and climate. No one explanation can be universally applied to all populations. Three measurements of height; standing height, sitting height, and sub-ischial height were examined for variation in sexual dimorphism. Univariate and multivariate statistical tests were performed to determine if significant variation in sexual dimorphism was evident among the groups sampled. Further, tests were performed to determine which component of stature contributes more to the variability in sexual dimorphism.

Results of this study indicate that the groups of the Northwest coast and Siberia both exhibited a pattttern of low sexual dimorphism relative to the inland North American groups. It is suggested that a more recent ancestry between the Northwest coast and Siberian groups is partly responsible for a similar pattern of dimorphism. Further, it is suggested that a long-standing adaptation to a cold

climate in Siberia is evidenced in the low dimorphism of the Northwest coast and Siberian groups. Leg length contributed more to group variability, but it is known that leg length is more susceptible to environmental changes. This study suggests that the differences in sexual dimorphism patterns in North America and the similarities in patterning of the Northwest Coast groups and Siberian groups are a reflection of the involvement of a combination of genetic and environmental factors.

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CHAPTER 1

OVERVIEW

Introduction

It is well known that in all populations, men are physically larger on average than women. Researchers are interested in determining the mechanisms behind this size difference in the sexes. Considered have been evolutionary forces, nutritional differences, behavioral differences, environmental effects, and sexual dimorphism in other organisms. Explanations which were appropriate to certain circumstances have been proposed, but no one explanation applies universally to all populations. Several forces may be operating at once to produce sexual dimorphism, or any one force may produce sexual dimorphism under certain circumstances.

This study was conducted to determine the patterning of sexual dimorphism in height in North American Indians, and compare the North American patterning with the patterning of Siberian groups. A similar patterning of sexual dimorphism could suggest more recent ancestry between groups, similar selective forces operating on the groups, or a common environment.

It was also of interest to ascertain which components of stature (sitting height and sub-ischial height) contributed most to the variability of the groups. I discuss common explanations for differing patterns of sexual dimorphism. Also important was how climate and natural selection affect growth patterns.

Data for standing height, sitting height, and sub-ischial height for various groups of North American Indians were available. Data from these groups were compared with similar data from Siberian groups to test for significant differences in sexual dimorphism among groups. Tests were also performed to determine which component of stature contributed more to sexual dimorphism. In examining sexual dimorphism in my sample, four questions were addressed:

1. Are there patterned differences in sexual dimorphism among the groups sampled?

2. Are there sex and/or population differences in the pattern of intrinsic variation in sitting height and leg length?

3. Is sitting height or is leg length more intrinsically variable within populations?

4. Is sitting height or is leg length more intrinsically variable among populations?

The data utilized in this study were collected by Franz Boas and his associates at the turn of the century.

Franz Boas

Franz Boas came to the United States from his native Germany in 1886. He conducted fieldwork on the Northwest Coast for over half a century from 1886-1931. Boas is known as the "father of ethnography." Boas wanted to present the people he studied not from his own point of view, but from the point of view of how people perceived their own culture. At this time, anthropology was heavily concerned with theory, and not so much with method. Boas' ethnographic research on the Northwest Coast focused on the need for more fact and less speculation. He emphasized both an empirical and an inductive approach to data collection and analysis (Rohner, 1969). His goal was to help shed light upon the agents that have shaped a culture by attempting a historical reconstruction (Rohner, 1969). Indeed, Boas was the first person to systematically distinguish the various language and tribal groupings on the N.W.Coast (Rohner, 1969). Boas' research in physical anthropology was primarily in anthropometry. His research on the N.W. Coast included taking body measurements, collecting skeletal material, and photographing body types (Rohner, 1969). Boas measured many subjects himself. Those subjects not measured by Boas himself were measured by anthropometrists trained by Boas. Until the turn of the century, there were no professional anthropologists. Boas, and his fellow anthropologists of the time came from other academic backgrounds, but they were very interested in recording as much about North American Indians as possible before their customs disappeared.

The Northwest Coast data were mostly collected during a research expedition (The Jesup North Pacific Expedition) that took place from 1887-1901. The purpose of the Jesup Expedition was to clarify some issues regarding the origin of the North American Indians raised by 19th century scholars.

Boas has also made numerous contributions to the studies of growth and variability. One of Boas' contributions was the demonstration that the influence of the environment is as strong, or stronger than heredity in influencing the expression of the human phenotype (Bogin, 1988). Boas was also one of the first to demonstrate the importance of calculating growth velocities from the measurements of individuals rather than from sample means (Tanner, 1978; Bogin, 1988).

The Boas data on North American Indians (Amerindians) and Siberians would have been lost to us had it not been for the efforts of Dr. Richard Jantz in recovering the data and setting up a data base for researchers to use. Jantz discovered the original data sheets stored at the American Museum of Natural History (Jantz et al., 1992). The data comprise more than 15,000 Amerindians and Siberians of all age groups, and measurements for 12 linear and post cranial dimensions (Szathmary, 1995).

Sexual Dimorphism

The term *sexual dimorphism* refers to the differences between the sexes in body size and proportions. These size (and shape) differences are the result of a complex interaction of environmental forces and the action of many genes (Molnar, 1975; Frayer and Wolpoff, 1985). These size differences occur primarily in adults, indicating that they are linked to hormonal events occurring at puberty (Frayer and Wolpoff, 1985). Males are taller on average than females in every known population (Eveleth, 1976; Gray and Wolfe, 1980). Males tend to be larger than females by an average of five to 10 percent (Molnar, 1975; Eveleth, 1976; Rogers and Mukherjee, 1991; Gaulin and Boster, 1992). The size of this sex difference is not the same for every population.

There is an evolutionary trend toward a reduction in sexual dimorphism (Brace, 1972, 1973; Frayer and Wolpoff, 1985). Krantz (1982) states that sexual dimorphism began its reduction (evolutionarily) with pithecanthropines, who were larger-brained. According to Krantz (1982), there are three phases of dimorphism in the fossil record. First, there were size and dental differences; then just size differences; finally, there were pelvic distinctions and minor size differences. These phases correspond approximately with the Miocene, Pliocene, and Pleistocene geological epochs.

Patterns of sexual dimorphism are variable from population to population. The exact cause of this variation is not known. Adaptive factors such as climate, activity patterns, nutritional abundance, and mate competition have long been analyzed as possible causes of sexual dimorphism.

These factors are thought to produce sexual dimorphism by creating differing selection pressures on each sex. The sexes thus adapt independently (Hall, 1978; Frayer and Wolpoff, 1985). Conversely, some researchers argue against independent adaptation of the sexes. Rogers and Mukherjee (1991) state that since the additive genetic covariances between males and female length measurements are high, the genes for such characters affect males and females in the same manner. The mean of the two sexes responds to selection much faster than does sexual dimorphism.

Frayer and Wolpoff (1985) describe the literature on sexual dimorphism as an examination of the two separate perspectives of ultimate or proximate causation. Ultimate causation models look at sexual dimorphism as a genetic adaptation to a variety of ecological, social, or economic factors, and commonly include selection as the primary explanatory mechanism. The proximate causation model views sexual dimorphism as a response to nutritional stress or improvements in the environment of growing adolescents. These nongenetic factors can explain secular trends (the offspring are larger than the parents) for increases in sexual dimorphism in modern groups or over periods of nutritional changes. Ultimate causation models do not necessarily explain short-term changes in sexual dimorphism

(Frayer and Wolpoff, 1985).

CHAPTER 2

SEXUAL DIMORPHISM IN HEIGHT:
A REVIEW OF COMMON EXPLANATIONS

Sexual Dimorphism and Nutritional Status

Several studies have focused on nutritional status as a major factor in sexual dimorphism. It is known that poor nutrition adversely affects growth in stature. The general premise of a nutritional cause of sexual dimorphism differences is that populations experiencing nutritional/protein deficiencies tend to experience a reduction in sexual dimorphism and those populations with an abundance of nutritional resources maintain greater dimorphism. The foundation of this premise is the proposal that male growth patterns are more sensitive to nutritional stress than female growth patterns. Males suffering nutritional deprivation suffer a greater reduction in adult stature than females suffering similar deprivations (Greulich, 1951, 1957; Brauer, 1982; Frayer and Wolpoff, 1985). Males show a greater impairment in long bone length (Frayer and Wolpoff, 1985). When experiencing conditions of nutritional stress, females are adversely affected, but only to a degree. However, males are affected to such an extent that they do not reach their expected growth potential. Therefore, populations with inadequate nutritional resources will be characterized by short females, even shorter males, and low sexual dimorphism in stature. With improved nutrition, a population will have both taller males and taller females, but the male gain is greater than the female gain, resulting in greater dimorphism (Wolfe and Gray, 1982). The following is a review of some major studies of this nature, and their findings.

Hamilton (1975) agrees that female growth patterns are less affected by poor nutrition and explains that this is due to the reproductive demands of females. According to Hamilton, successful reproduction makes more exacting physiological demands on female size, whereas male size can be considered irrelevant to reproduction, except for its relationship to sexual selection and survival. Thus, females are smaller than males because their energy reserves go toward reproduction. The strongest selective factor favoring small female size is lactation (Hamilton, 1982 as cited from W.H.O. 1973). Both pregnancy and lactation produce increased caloric need. According to Hamilton (1982), females in nontechnological societies spend much of their reproductive years in a state of lactation, thus, a selective force has operated throughout human evolution to limit female body size. Smaller female size allows for the extra calories to be used for lactation and reproduction and not to maintain a larger body. Females are experiencing stabilizing selection; there is a limit to how small females can be and still successfully reproduce. Thus, sexual dimorphism exists because selection operates to maintain smaller females to enhance reproduction. Females are not as adversely affected by poor nutrition as males because a certain size must be maintained for successful reproduction.

Frayer and Wolpoff (1985) state that females are less affected in growth by nutritional deprivation, supposedly because of reproductive demands, storage of more subcutaneous fat, and overall smaller body size. Sexual dimorphism in body size is reduced as the mean male and female adult stature's decrease. Thus, poor nutrition may explain the reduction in dimorphism with the arrival of agriculture. Indeed, Hamilton (1975) found that the two populations in her study who were more committed to agricultural practices were also the least dimorphic.

Grant (1993) compared the degree of sexual dimorphism in East Tennessee skeletal samples ranging from Middle/Late Archaic hunter-gatherers to Late Mississippian agriculturalists. Grant's research illustrated a significant decrease in size-related sexual dimorphism from the hunter-gatherer to the agricultural samples. A significant increase in size for males and females over time was evident, although nutritional quality declined. Grant concluded that the decrease in sexual dimorphism was likely due to reduction in the male growth rate, caused by nutritional and disease-related stress.

Eveleth (1975) conducted a study on sexual dimorphism in stature among Negroes, Europeans, and Amerindians. Eveleth found that the greatest amount of sexual dimorphism existed in Amerindians. She concluded that the greater sexual dimorphism among Amerindians is likely due to genetic, rather than environmental factors since it would be difficult to conceive of Amerindians as a whole being better nourished than Europeans as a whole, though she states that it is conceivable that boys are treated better in those societies than girls.

Stini (1969) examined the relative effects of protein deficiency on the skeletal maturation of 515 apparently healthy boys and girls of Heliconia, Columbia. The diets of the children were, in all cases, chronically deficient in animal protein. There were no apparent sex differences in protein intake. Weaning took place at approximately nine months of age for both sexes. Stini found that the nutritionally-deprived females appeared to experience a form of catchup growth beginning in the adolescent period, while nutritionally-deprived males appeared more severely growth retarded throughout adolescence. Thus, the long-term effects of protein deficiency were more pronounced in males. According to Stini, this results in a reduction of stature that is most pronounced in boys, and a concomitant reduction in sexual dimorphism for total body size. Birkbeck and Lee (1973) conducted a similar study on Indians of British Columbia, and they found similar results in that nutritional factors can greatly modify the ability to achieve growth potential.

In a separate study, Stini (1975) examined body size of adults from Columbia. These adults were suffering from the effects of protein deficiency. Stini found that adults suffering nutritional stress were on average shorter and had less muscle mass than the better nourished groups. Stini proposed that muscle mass is a direct indicator of metabolic activity and correlates with the body's requirements for energy and protein. Therefore, adults with reduced stature and muscle mass need to eat less food than people with more skeletal and muscle tissue. Stini argues that this was a beneficial adaptation to undernutrition. Stini believed that size reduction associated with malnutrition took place during the prenatal and early postnatal growth periods. It was a developmental change, adjusting the growth rate and size of an individual to his environment, and not the result of genetic selection for small body size. Stini argued for developmental plasticity, since genetic adaptation exclusively would usually result in a stereotypic and potentially maladaptive and rigid response.

Gray and Wolfe (1980) conducted a thorough study of sexual dimorphism in stature in relation to marriage systems, nutritional status, settlement size, the presence of milking herds, and climate. Gray and Wolfe found that those societies with poor nutrition (low protein availability) have lower degrees of sexual dimorphism in stature, thus supporting the findings of Tobias (1975). Gray and Wolfe's (1980) study also supports the research of Eveleth (1975) and Stini (1971, 1975, 1982) who found that the nutritional status of a society cannot be gauged by the degree of sexual dimorphism in stature since the greatest and least degrees of sexual dimorphism in stature is found in those societies with high protein availability.

Hall's (1978) study is of particular interest because, like the present study it utilized Boas data from many of the same groups. Hall (1978) investigated sexual dimorphism for size using Boas data on 12 anthropometric measures from adults in seven nineteenth century populations of British Columbia. Hall found both secular and age-related changes in most of the traits. Hall found that secular changes affected males more intensely than females. The degree of sexual dimorphism increased directly with male average size for stature and other linear measures.

Hall reviewed other studies of sexual dimorphism for size that emphasized the greater susceptibility of male growth processes to the environment than female growth processes. Hall (1978) cautioned that "stature has been used as a measure of general size because it is an obvious size attribute and because more data are available on stature than any other anthropometric measure, not because it is the most representative or most interpretable measure" (p.161). Hall was interested in determining whether variation in male or female average size contributed more to differing degrees of sexual dimorphism. She concluded that greater size effects did occur in males than in females. "Male samples tended to have coefficients of variation slightly higher than those of the female samples from the same populations in most linear traits related to body size [including stature, sitting height, and sub-ischial height] and the female samples tended to have larger coefficients of variation in the other traits (head breadth, facial height, facial breadth, nasal height, and nasal breadth)" (Hall, 1978: p.165).

Hall found that not one trait had the same sex showing higher values for all seven of her paired samples (divided into decade age groups) analyzed. Hall's analysis suggested that "problems are involved in separating secular changes from age-related effects in size in samples that include adults of all ages" (Hall, 1978: p.163). Hall determined that within the samples and traits analyzed in her study, variation in sexual dimorphism may be controlled to a larger extent by variation in average male size than by variation in female size. Hall's analysis demonstrated that the two sexes respond differently to environmental changes, and more significantly, that separate body parts respond differently.

The differential growth of bodily parts is an allometric response. *Allometry* refers to the relationship between increases in the dimensions of one part of the body in relation to the growth of the whole organism or other parts (Lieberman, 1982). This leads to changes in bodily proportions. Both positive and negative allometry take place in the ontogeny of human development (e.g., head versus body growth, leg versus trunk growth) (Bogin, 1988).

Body proportions are related to coping with climatic stress (Brues, 1977). Separate body parts respond differently to stressors. It appears that allometry enjoys a higher priority than absolute size when environmental stress is present (Stini, 1971). Hall remarked that stature incorporates numerous genotypic and phenotypic influences thereby making studies of stature difficult to interpret. Hall's study supports the conclusions of Tobias (1975), Stini (1975), and Hamilton (1975).

Frayer and Wolpoff (1985) suggested that a possible long-term effect of nutritional deprivation is a reduction in body size for both sexes. With chronic nutritional shortages, selection would operate to reduce body size with respect to energy efficiency. Sexual dimorphism would decrease as males would be under more intense selection. Any selection for body size would result in reduced sexual dimorphism since body size is positively correlated with the degree of sexual dimorphism.

The above studies refer to long-term nutritional shortages as being responsible for stunted adult growth. Short-term effects can be remedied through catch-up growth (a higher than normal velocity of growth), depending on the severity of the insult and the age at which it occurred (Eveleth and Tanner, 1975). A child who suffers for a short period from an illness or malnutrition is able to return to, or at least approach, his regular course of growth when conditions improve (Eveleth and Tanner, 1975). Catch-up growth may completely restore the situation to normal or it may be insufficient to do so (Eveleth and Tanner, 1975).

The relationship between nutritional status and sexual dimorphism in stature is indistinct, pointing to the possibility of multiple elements operating concurrently or a factor affecting each sex differently. Hiernaux and Hartono (1980) concluded that sexual dimorphism in stature of the adult Hadza of Tanzania may be due to possible sex differences in access to resources between societies during growth. Their analysis suggests that females are favored in terms of work and food. Thus, nutritional status cannot be proven to be a singular explanation for sexual dimorphism, but perhaps one of several factors affecting growth.

Dimorphism and Mating Practices

Some researchers have concluded that sexual dimorphism may result from natural selection, sexual selection, or both. Darwin (1874) explained how natural selection operating differentially on males and females arises from their individual roles in reproduction, or from competition between the sexes for resources, and leads to adaptive sexual dimorphism. Darwin stated that the strength of sexual selection is enhanced by a polygamous mating system, but could also be evident in a monogamous system due to male competition for early-breeding females. Sexual dimorphism arising from natural selection requires that males and females follow different ways of life and employ the dimorphic characters adaptively in their distinct modes of survival or reproduction (Darwin, 1874; Lande, 1980; Frayer and Wolpoff, 1985). Sexual dimorphism arising from sexual selection requires its fullest development at sexual maturity, perhaps only in the mating season, and if the dimorphic character functions mainly in one sex to confer a mating advantage on individuals with more extreme development of the character (Darwin, 1874; Lande, 1980; Frayer and Wolpoff, 1985).

Trivers (1972) has extended Darwin's (1871) concept of intrasexual selection. Triver's proposes that individuals of each sex have limited resource budgets that they can invest in their offspring or related individuals. One sex usually invests more than the other. In mammals, the female typically invests more due to the costs of gestation and lactation. Therefore, females cannot reproduce offspring at the rate at which males can father them. The reproductive success of females is limited to the number of offspring they can produce and raise. The reproductive success of males is limited by factors affecting the number of females they can fertilize.

This supposition explains why, among mammals, polygyny is common and polyandry is rare or non-existent. The advantages to a female of maintaining access to several males will usually be less than the advantages to a male of maintaining mating access to several females (Trivers, 1972).

Price (1984) offers several hypotheses for the evolution of sexual dimorphism based upon his research for size sexual dimorphism in Darwin's finches. Price divided natural selection into two components: *survival selection*, which arises from variance in mortality and *fertility* *selection*, which arises from variance in fertility. These types of selection may act differently in the two sexes, and thus lead to sexual dimorphism.

In Price's two niche variation hypotheses, the only variation is in whether males or females are predicted to be closer to the survival selection optimum, that is, which sex suffers less mortality. In one scheme, morphological differences between the two sexes allow each sex to occupy a different niche in the nonbreeding season. Thus, there are two survival optima. Once there are sex differences, dimorphism is accentuated through competition. The main prediction is that the population as a whole will be under disruptive survival selection.

According to the second niche survival hypothesis, dimorphism evolves in response to selection pressures during the breeding season. More dimorphic pairs have greater reproductive success than less dimorphic pairs, because they are able to exploit a greater diversity of resources. Selection acts such that both sexes are held off at survival optimum. In both types of niche variation hypotheses, the two sexes will forage differently.

Two additional hypotheses for the evolution of sexual dimorphism have fertility or sexual selection as primarily confined to one sex. An example of fertility selection is the small body size selected for in females due to their greater reproductive investment. Fertility selection is considered more important in females and males are closer to the survival optimum. In sexual selection, larger body size is selected for. Selection is more intense in males and females will be closer to the survival optimum.

Price's study of sexual dimorphism in Darwin's finches concluded that there was no evidence of ecological competition between the sexes in the breeding season involved in the maintenance or evolution of dimorphism. It was also concluded that to some extent, fertility selection and sexual selection may be interrelated, because when fertility selection is present females are below the survival optimum, resulting in an unbalanced sex ratio and the increase in the potential for sexual selection. Thus, fertility and sexual selection can be implicated in the evolution of sexual dimorphism in Darwin's finches.

Some researchers have suggested that mating practices can predict the pattern of sexual dimorphism in stature of humans (see Clutton-Brock and Harvey, 1978; Alexander et al., 1979; Lande, 1980). The sexes experience divergent selection pressures and sexual dimorphism often evolves (Gaulin and Boster, 1992; see Lande, 1980). An example of this is the polygynous mating system, where certain males monopolize breeding opportunities. Selection pressures operate on the males to maximize their mating success (i.e., larger size). Females do not have these same selection pressures operating on them. In contrast, in effective monogamous mating systems, competition for mates is not disproportionate in either sex. Selection pressures on males and females do not differ and sexual dimorphism does not evolve (Gaulin and Boster, 1992; Armelegos and Van Gerven, 1980; see Lande, 1980). The comparative method has confirmed these predicted correlations between sexual dimorphism and mating practices (Gaulin and Boster, 1992). "If additive genetic variation for sexual dimorphism is always available through mutation and recombination, equilibrium occurs when the average phenotype of males and of females is each at a local maximum of fitness. Thus, provided there is genetic variation in sexual dimorphism, correlated selective responses between the sexes do not prevent the eventual evolution of both sexes to a locally optimum phenotype" (Lande, 1980: pp.299-300). As data for actual mating practices are unavailable, marriage systems are generally used as a gauge of the intensity of sexual selection (Alexander et al., 1979; Gray and Wolfe, 1980; Gaulin and Boster, 1992).

Alexander et al., (1979) conducted an analysis of sexual dimorphism based on Darwin's theory of sexual selection. Darwin explains sexual dimorphism in terms of mate competition generating different selective pressures on each sex, with one sex being the competitor and one being the object in demand. In polygynous societies, where one male mates with several females, fewer males than females will contribute their genes to successive generations. Sexual competition is stronger in the males as they compete for females. Therefore, reproductive success will vary more among males than females. In monogamous societies, where one male mates with one female (presumably), reproductive success is expected to be about the same for each sex.

Alexander et al., (1979) defined three separate human marriage systems: polygyny, ecologically imposed monogamy (EIM), and socially imposed monogamy (SIM). According to Alexander et al., (1979), the marriage systems involving polygyny and socially imposed monogamy encourage male to male competitions for mates and thus promotes sexual dimorphism. The ecologically imposed monogamous system does not promote male to male competition and sexual dimorphism is not as evident in this type of marriage system.

Gray and Wolfe (1980) pointed out several possible flaws with the Alexander et al., (1979) study. First, there is a question of whether standard methodological procedures for cross-cultural research were used in the collecting and coding of the marriage system data. Secondly, questionable data were used involving visual estimations of height in at least three cases. Finally, another case of questionable data is cited involving different handling of height ratio calculations for two different groups. Despite these problems with the Alexander et al., data, Gray and Wolfe (1980) acknowledge the possibility that the degree of sexual dimorphism of stature is influenced by marriage practices.

Gray and Wolfe (1980) conducted a study of sexual dimorphism in stature involving data for marriage systems, nutritional status, settlement size, the presence of milking herds, and climate. With respect to mating practices, they concluded that while greater mean male height is associated with polygynous marriage systems, marriage practices did not influence the degree of sexual dimorphism in stature. Thus their results do not support the findings of Alexander et al., (1979). Their results further suggest that sexual dimorphism has a strong genetic component but is affected by dietary factors. They also discovered that "the most sexually dimorphic societies are those with the tallest males and/or the shortest females" (Gray and Wolfe, 1980: p.445).

Sex Differences in Behavior

Frayer and Wolpoff (1985) have offered a hypothesis that is based upon Darwin's (1871) theory of natural selection that sex differences could arise under natural selection if the two sexes differ in habit. They argue that differences in sex roles may be an important factor in deciding the degree of sexual dimorphism. This model did not apply to the fossil hominid groups examined because the range of economic systems examined in the study did not characterize most of the fossil hominid groups included in the study. All of the prehistoric populations examined were basically hunter-gatherers (See Wolpoff, 1976 for a comparison of Australopithecine sexual dimorphism with that of living primates).

Murdock and Provost (1973) conducted a cross-cultural statistical analysis of the sexual division of labor. This study codes 50 different technological activities divided by sex. The sexual division of labor is fairly strict for hunting and gathering groups. The role differentiation is not as clear-cut for agricultural groups. Therefore, one would expect greater sexual dimorphism in hunting and gathering groups as compared to agriculturalists (Frayer, 1980).

Frayer and Wolpoff (1985) cite the Murdock and Provost study as evidence for the division of labor by sex in hunting and gathering societies being well defined with males assuming the more dangerous activities associated with hunting. In agricultural societies, activities are less distinct by sex. Frayer (1980) found that most of the relative reduction in dimorphism of stature is due to greater declines in male dimensions, explained as a response to decreased need for large body size with the development of advanced hunting techniques.

Wolfe and Gray's (1980) study does not support this hypothesis. Neither does that of Collier (1993). Collier tested Frayer's (1980) hypothesis that sexual dimorphism is greater in big-game hunting and gathering groups. Two Eskimo groups were examined, one of which was associated with big-game hunting (whaling), the other a salmon fishing peoples. He found that the two populations had different relative sexual dimorphism for different parts of the body.

The big-game hunters had the lower multivariate dimorphism in the humerus, the structure likely to be under greatest exertion in big-game hunting activities. The big-game hunters did have higher robusticity, as predicted by Frayer's model, but the females were also more robust, resulting in low sexual dimorphism in some features.

Ruff and Hayes (1983), Ruff (1987), and Ruff et.al., (1984) have attempted to explain sexual dimorphism based on the functional aspects of the postcranial skeleton. The theory is presented that functional differences due to separate activities of the two sexes will be reflected in different mechanical forces exerted on the lower limb bones.

Ruff (1987) examined cross-sectional geometric properties of the human femur and tibia and compared male and female samples from the Middle Paleolithic to a large modern U.S. sample. His study detected a consistent decline in sexual dimorphism from hunting and gathering to agricultural to industrial subsistence strategies in a measure of relative anteroposterior bending strength of the femur and tibia in the knee region. The trend of reduced sexual dimorphism in cross sectional shape is largely evident in external breadth. There was a lack of significant overlap between subsistence categories.

According to Ruff (1987), this trend parallels and is indicative of reductions in the sexual division of labor and differences in the relative mobility of males and females. Regarding mechanical loadings, Ruff states that the relative anteroposterier to mediolateral loading of the lower limb has declined more through time in males than in females.

An earlier study by Ruff and Hayes (1983) of skeletal material from the Pecos Pueblo, New Mexico archaeological site detected several sex-related differences in lower limb bone structure. According to the authors, these differences likely reflected differing mechanical forces or loadings, placed upon the male and female lower limb bones during life. Male lower limb bones were adapted for relatively greater anteropoterior bending, and female lower limb bones for greater mediolateral bending. The authors propose two possible explanations for this sex difference, the first being that males may have participated more in running activities, producing high anteroposterior bending loads in the lower limb, especially around the knee. Secondly, the sex difference may be due to the relatively greater pelvic breadth and consequently higher mediolateral bending loads about the hip in females.

Ruff (1987) states that overall size (e.g., stature) is an imprecise indicator of biological adaptation. Changes in bone geometry and shape may be more informative about the relationship of postcranial sexual dimorphism and environmental factors, specifically adaptation to specific mechanical forces that are indicative of functional use and thus behavioral differences (Ruff et al., 1984; Ruff, 1987). Ruff's (1987) study supports that of Frayer (1980) in that both conclude that the degree of sexual dimorphism within a population is roughly proportional to the exclusivity of the division of labor by sex.

Dimorphism and Settlement Type

Finkel (1982) states that settlement type can suggest the degree of social complexity and the differing sex roles taking place in the society. In village agricultural societies, males and females contribute equally in agricultural activities. Frayer (1980) considers equivalent sex roles in farming to be one major cause of the reduction of percent sexual dimorphism from hunting and gathering societies to the early agricultural ones. Finkel (1982) states that as agriculture caused an increased food supply and increased population density, most of the population turned to nonagricultural occupations and urbanization increased. In proto-urban and urban societies, certain activities became male dominated, possibly because these activities represented a major source of economic livelihood. Different specializations resulted in a divergent distribution of wealth and a stratification of social classes arose. Women's social roles differentiated, depending on class and occupation. Urban societies are usually supported by an agricultural base outside the urban area.

According to Finkel (1982), if a division of labor is most intensified in upper socioeconomic classes, it can be assumed that class differences in sexual dimorphism patterning would exist in an urban society, as females in lower socioeconomic classes would likely play a greater role in subsistence. The upper classes would therefore have a greater percent sexual dimorphism. It can be assumed that class differences in sexual dimorphism would probably involve many external influences, and not simply be a matter of subsistence activities.

Dimorphism and Genetics

Some researchers have emphasized a strong genetic component involved in sexual dimorphism in height. Height is a polygenic character, meaning that the genetic factors determining height are represented by several loci and have several alleles. Thus, it is difficult to establish exactly which genes are responsible for height and which external factors are accountable for height variations. Recent studies have examined sexual dimorphism as it relates to sexual selection and parental investment theory.

Cheverud and Leutenegger (1986), wanted to consider phylogenetic relationships (historical constraints) in their analysis of sexual dimorphism in weight among primates. They found that "phylogenetic relationship is the most important factor affecting the distribution of sexual dimorphism among primate species, closely followed in importance by scaling (i.e., the effects of size)" (p.917).

In researching size and scaling effects for sexual dimorphism in size, Cheverud and Leutenegger (1986) hypothesized that "size acts as a nonadaptive factor in the evolution of sexual dimorphism, in that direct selection on size will result in the evolution of sexual dimorphism for size if the additive genetic variances of the sexes differ" (p.917). Sexual dimorphism arises through stabilizing selection, or if the phenotypic effects of mutation differ between the two sexes. Therefore, "selection is not for the independent adaptation of the sexes, but evolves as the unintended sequelae of equivalent selection on size in both sexes" (Cheverud and Leutenegger, 1986: p.917). Rogers and Mukherjee (1991) state that this theory is complicated by the fact that homologous characters in males and females typically show high genetic correlations, which suggests that many genes have very similar effects in both sexes. Therefore, "selection for increased stature in males may increase the stature in both sexes, and have little effect on sexual dimorphism" (p.227).

Rogers and Mukherjee (1991) used a classical data set (see Pearson and Lee, 1903) to predict the effect of selection on sexual dimorphism and on the population means of stature, span, and cubit in humans. Sexual dimorphism was measured as the difference between male and female characters. A secular trend was evident in the data. Rogers and Mukherjee state that their analysis shows that sexual dimorphism responds to selection more slowly than the population mean. Indeed, "the population mean responds to selection about 65 times as fast as does sexual dimorphism" (p.231). Rogers and Mukherjee conclude that since the additive genetic covariances between male and female length measurements are extremely high, the genes for such characters presumably affect males and females in the same way. The mean of the two sexes responds to selection much faster than does sexual dimorphism. Rogers and Mukherjee state that Cheverud and Leutenegger (1986) were correct in arguing that selection for larger mean body size could generate changes in sexual dimorphism, but that the response seems too weak to account for the observed relationship between dimorphism and body size in primates. Regarding studies of sexual selection, Rogers and Mukherjee (1991) state that "Mating systems have changed in some societies much too rapidly to be tracked by natural selection . . . [Therefore,] this relationship may be weak or absent even if human sexual dimorphism has been shaped by natural selection" (p.233). Thus, the mating strategy theories for sexual dimorphism are discounted.

The above studies support strong genetic factors as a primary explanation for sexual dimorphism. While undoubtably, external factors affect growth, a great amount of time is necessary for external factors to affect sexual dimorphism on a population-wide scale.

Growth and Environment

Growth and development are influenced by climatic factors such as temperature, altitude, and solar radiation, as well as environmental factors such as nutritional intake.

Franz Boas was an early pioneer of growth studies. In fact, it was Boas who introduced growth and development studies into the practice and teaching of Physical Anthropology in North America (Tanner, 1978). Franz Boas was one of the first to conduct a study on morphological differences and how they relate to environment. Boas conducted studies of the changes in head form and bodily form in descendants of immigrants to the United States (see Boas, 1912). A more recent study of descendants of immigrants on height differences is that of Greulich (1957).

Greulich (1957) compared the physical growth and development of American-born and Native Japanese children. Among those variables compared were standing height, sitting height, and sitting height/standing height ratio (sub-ischial height). At every age, American-born Japanese children exceeded the native Japanese children in standing height and sitting height. All differences were statistically significant except for the 18-year old girls. American-born Japanese children had relatively longer legs up to about the time of puberty, which Greulich attributed to a greater momentum of growth during early childhood and before puberty. After puberty, the leg lengths of American-born Japanese and native Japanese children became indistinguishable at every sex and age group. Greulich credits the longer leg length of the prepubescent American-born Japanese with good nutrition and a favorable environment as leg length is usually considered a racial character that is genetically determined and controlled. Greulich (1957) points out that the real racial character involved is the leg length of the adult, which will "probably not be appreciably different in American-born and native Japanese children when their growth is completed" (p.513). This study showed greater female response in secular increases in stature of native Japanese in the first half of this century.

The above type of study reflects secular trend. Secular trend can be described as concerning increments that vary with social stratum and with the cohort of offspring under various conditions of assortative mating of their parent's stature (Wolanski and Kasprzak, 1976). While sexual dimorphism may change in a secular manner from one generation to the next, population-wide changes in sexual dimorphism are reflecting a long-term growth variation. As stated previously, sexual dimorphism changes much less rapidly than the population mean for height (see Rogers and Mukherjee, 1991).

According to Frisancho (1981), from previous growth studies, it can be implied that populations suffering chronic poor nutrition have a pattern of growth characterized by slow growth during childhood and adolescence, a late adolescence growth spurt, and a prolonged period of growth. Because of the cumulative effects of prenatal undernutrition, prenatal growth retardation, and chronic undernutrition after birth, postnatal linear growth is slow and leads to reduced adult body size (Frisancho, 1981).

Growth and Climate

Climatic factors may exert selective pressures on the phenotype. Roberts (1978) explains that climate tends to remain constant over long periods of time, therefore, selection pressures operate in the same direction generation after generation. According to Roberts (1978), because climatic factors change slowly over wide areas, characters that vary with climate tend to show clinal variation, by contrast to the variation produced in response to other types of environmental variation (such as nonclimatic habitat factors). Climatic gradients occur in parallel in different continents so that intercontinental comparisons are possible. If populations long separated genetically show parallel morphological gradients, the theory that they are associated with climate is strengthened.

The first morphological character to be examined for a relationship with climate was the nasal index (Roberts, 1978; Franciscus and Long, 1991). The nasal index reflects the breadth of the nose relative to its height. A classic study by Thompson and Buxton (1923) examined the mean nasal index in indigenous peoples in relation to their climates. The nasal index was correlated with mean annual temperature and humidity.

A recent study by Franciscus and Long (1991) supports the adaptive role for human nasal index variation. According to Franciscus and Long, nasal height is more strongly correlated with temperature, covarying negatively, whereas nasal breadth is more strongly correlated with humidity, covarying positively. The nasal index shows a higher correlation with climatic gradients than either nasal height or nasal breadth alone. These associations have been explained as evolutionary adaptations to expand respiratory heat and moisture exchange in nasal mucosa to moderate body water loss and maintain thermal equilibrium, as well as to prevent lung alveoli and ciliary damage (Thompson and Buxton, 1923; Roberts, 1978; Franciscus and Long, 1991). A narrow high nose functions better in cold, dry climates by warming and moistening inspired air as well as recovering heat and moisture from expired air. A low wide nose better dissipates heat in hot, humid climates (Thompson and Buxton, 1923; Franciscus and Long, 1991).

Franciscus and Long (1991) found no sexual dimorphism pattern in the relative variation and covariation of nasal height and breadth, nor did different variance-covariance patterns appear within different human populations.

Roberts (1978) examined a series of 300 samples of males from different populations around the world. The purpose of his study was to associate climatic variations with differences in lower limb length. His study showed a marked tendency toward regional groupings of relative sitting height (leg length) mean values. In Africa and northern tropical grasslands, most of the lowest values occurred in the hottest regions, and low to medium values tended to occupy forest (except Pygmy samples) and less hot areas. Medium values occurred at all latitudes, but mainly in the Mediterranean area. Asia's lowest means appeared in the warmer south, with higher values in the cooler mountains and other cool areas. The highest values were found only in very cold areas. In American samples, low means occurred only in the hot desert areas and in the lower hot areas of Central America. High values occurred at higher altitudes and latitudes, and highest values occurred in the Arctic and Subarctic, and a single Andean sample. European samples had medium to high values, as did the samples from the Pacific area. A relationship with mean temperature is suggested. For relative sitting height, there was a highly significant linear association with mean annual temperature ($r = -.619$, $b = -.639$). Nearly two-fifths of the total variance is ascribable to mean annual temperature, therefore, body proportions are more closely related to temperature than is absolute size. Roberts found agreement between independent male and females series. Thus, Roberts' study confirms the relationship of relative sitting height with temperature suggested by the general geographic pattern. A link between climate and the relative length of the lower limbs is suggested. Robert's study suggests that in colder climates, people tend to be heavier, with relatively larger trunks and shorter legs, while peoples in hotter climates tend be relatively lighter and longer legged. Roberts (1978) concludes that "physiological phenotypic variation and genetic differences in combinations probably account for the association [between climate and physique]. Of these two, the latter appears on present evidence to be predominant, and this implies that natural selection acting on the gene pools of populations is ultimately responsible for the physique/climate association" (p.70).

Besides increasing in length relative to stature, the lower limb seems to change shape and become more slender with increasing temperature. Roberts (1978) cites the zoological rules relating body size and proportions to environment. Bergmann's rule states that "within a polytypic warm-blooded species, the body size of the subspecies usually increases with decreasing mean temperature of its habitat" (Roberts, 1978: p.29). Increased size alone, with shape remaining the same, decreases the ratio of body surface to body volume (Brues, 1977). Therefore, populations inhabiting colder climates are usually larger than those of warm climates. Allen's rule states that "in warm-blooded species, the relative size of exposed portions of the body decreases with decrease of mean temperature" (Roberts, 1978: p.29). These rules are based on physical laws. "The larger the surface area of a body, the greater the loss or gain of heat by convection and radiation, and the greater the area over which evaporation can occur" (Roberts, 1978: p.29). For humans living in areas of high temperature, heat loss is vital and sweating is the main outlet for it. The amount of heat produced in working depends upon the body weight of an individual. An individual with slender limbs can lose relatively more heat than a person with more substantial limbs. Roberts states that Bergmann's rule is applicable to humans with some modification. A clearer definition of "body size" is necessary. Body size defined as stature is not applicable, whereas body size as defined in units of mass, such as body weight is appropriate.

Roberts states that there are disadvantages to using body weight.

> "It is a gross, complex character, combining indistinguishably measures of the amount of metabolically active tissue, of insulating tissue (e.g., subcutaneous fat), and of other metabolically inactive tissue. Thus the relationship shown may suggest in warm areas an actual reduction in the amount of heat-producing tissue or a decrease in the amount of insulating tissue or both . . . Moreover, it is a labile character, varying over short periods with food consumption and health. The climatic correlation may thus involve nutritional differences, or perhaps the residue of nutritional differentials during growth rather than genetic adaptation" (Roberts, 1978: p.31).

Roberts states that Allen's rule needs similar modification to separate "relative size" into its components of linearity and bulk. Therefore, body surface relative to mass in warm-blooded creatures tends to increase with increased temperature and the general principles of

Bergmann's and Allen's rules are applicable to humans (Mayr, 1956; Newman, 1953, 1956; Roberts, 1978). According to Newman (1953) for man we have a much larger series of measurements on wholly adult groups distributed over wide areas with tremendous climatic variations. Additionally, the vast amount of data on post-Pleistocene human skeletons provides a third dimension usually lacking in taxonomic studies. Therefore, it is likely that Bergmann's and Allen's rules may be more easily demonstrated in man than in other mammals.

Newman (1953) tested Bergmann's and Allen's rules on New World groups and found them applicable. A clinal distribution of stature was generally evident. In Indians and Eskimos, the distribution of average male stature showed a concentration of short peoples in the lower latitudes. In Northern North America, however, the stature cline is broken by the shorter Eskimo. Their short stature was attributed solely to their short legs, since Eskimo sitting height is not significantly different from other North American groups. According to Newman, this reduction in extremity length is in accordance with Allen's rule, and likely represents an adaptation favoring body heat retention. Newman concludes that the sustained clines in body size and proportions are due to adaptive changes taking place in the

New World. In their pattern of adaptive change the body size clines seem to follow Bergmann's rule. The extent to which adaptations in body size and proportions are inherited, and how the environment affects them is not clear. Newman states that it is clear that body build is influenced by both heredity and direct environmental factors but the relative potencies of these factors are unclear. In researching sexual dimorphism in height, Gray and Wolfe (1980) state that "climate is involved in only one significant association: Societies in cold climates tend to have lower mean male heights than do societies in warmer climates . . . Climate did not have a significant effect on sexual dimorphism in stature, although lower mean male height is associated with groups in colder climates" (p.452).

A singular factor has not been positively linked with sexual dimorphism. A combination of factors is most likely responsible. Indeed, it seems that nutrition, climate, settlement type, and sex differences in activities are linked. It would be difficult to separate out the effects of a particular factor. Underlying these factors is the effect of genetics. Cheverud (1988) states that the genetic and environmental causes of phenotypic variation tend to act on growth and development in a similar manner. Most environmentally caused phenotypic variants should have genetic counterparts and vice versa (Cheverud 1988). If one could separate out the external factors, there would still be the challenge of separating the phenotypic variants from the genetic variants.

The Genetics of Adult Stature

Adult stature is a continuous trait, meaning that it is measurable on a continuum. It has a fairly Normal distribution curve. This suggests that the determining factors are likely to be multiple--multiple genetic, multiple environmental, or a mixture of both (Susanne, 1975; Carter and Marshall, 1978; Tanner, 1978). Studies of familial resemblance for stature suggest that the genetic source of variation in the population depends on several, perhaps many, gene loci (Susanne, 1975; Eveleth and Tanner, 1975; Carter and Marshall, 1978 Tanner, 1978; Lande, 1980). There is an interaction between genetic and ecological factors. The internal environment of the organism also has an integrative role in this interaction (Wolanski, 1970). The internal environment refers to the process of homeostasis, which is regulated by genetic and nongenetic determinants, and by metabolic habits stabilized during the development of the individual (Wolanski, 1970). The internal environment is affected by some external environmental factors (Wolanski, 1970). Methods of analysis try to establish the role played by heredity and environment in determining a quantitative character and to analyze each of these two components as precisely as possible (Frezal and Bonaiti-Pellie, 1978).

The heritability (h^2) of a character refers to the genetic contribution to offspring for a character. Heritability is defined as the ratio of additive to phenotypic genetic variance (Falconer, 1960; van Vark and Howells, 1984).

In a panmitic population, for polygenic traits produced only by autosomal genetic factors, the following correlation coefficients would occur (Susanne, 1975):

mid parent-child	0.71
parent-child	0.50
sib-sib	0.50

The figures do not apply if dominance is involved in the expression of alleles or if X-linked genes also have an effect on the determination of a trait (Susanne, 1975).

Twin studies help to elucidate the genetics of growth. If amounts and rates of growth are totally controlled by the genotype, then correlation coefficients for monozygotic identical twins should be equal to 1.00, a perfect correlation, at all age periods, provided that the environment for growth is favorable or at least does not inhibit the growth of one or both twins (Friedlander, 1975; Bogin, 1988). One must assume that the parents are randomly selected from the population of potential mates. Studies of familial correlations in growth may also help to illuminate the role of genes and the environment. First-degree relatives should have higher correlations than second or third degree relatives. Theoretically, siblings, and parents and their offspring should share about 50 percent more of their genes than the amount shared at random between any two unrelated members of a breeding population (Bogin, 1988). Thus, siblings and parents and their offspring should have approximately equal correlations in stature. Siblings have shown higher correlations in stature, possibly due to the effect of a more similar environment for growth shared by siblings than by parent-offspring pairs (Susanne, 1975). Studies of familial correlations have shown difficulty in separating out the effect of a common environment versus genetic similarity between first-degree relatives living in the same household.

Any model of genetic structure that is applied to quantitative traits requires knowledge of either the additive genetic covariance matrix or the heritabilities of the individual traits (Relethford and Blangero, 1990). The heritability of a quantitative character is essentially a function of the population studied, since it depends on gene frequency and on the effect of the environment (Frezal and Bonaiti-Pellie, 1978). Some problems with the estimation of quantitative genetic parameters in natural populations arise because environmental effects may not be randomly distributed among related individuals (Susanne, 1975; Larsson and Forslund, 1992). For example, in many animal species, one parent, usually the mother, may influence the development and final adult size of traits of the offspring more than the other parent (Larsson and Forslund, 1992). Such maternal effects will affect the resemblance between relatives and therefore bias the heritability estimates and genetic correlations (Cheverud, 1988; Larsson and Forslund, 1992).

The examination of parent-offspring and mid-parent-offspring correlation coefficients suggests that anthropological measurements differ in the extent of their genetic determination, this being greatest in longitudinal body measurements, and least in circumference measurements of soft tissues and in measures of the nose and mouth (Susanne, 1975). The highest coefficients of the longitudinal measurements suggest greater influence by genetic factors and lesser influence of environmental factors and/or factors of dominance (Susanne, 1975).

Studies of sexual dimorphism should take into account external factors such as nutrition, climate, and behavioral differences, as well as underlying factors such as genetics. These factors have all been shown to affect growth processes and could contribute to sexual dimorphism either singularly or in combination.

CHAPTER 3

MATERIALS AND METHODS

Selection of the Sample

The population selected for this study consists of various North American Indians (Amerindians), and Siberian groups. The variables included in this examination are standing height (stature), sitting height, and sub-ischial height, as measured by Franz Boas at the turn of the century. Groups with sufficiently large sample sizes of at least 14 individuals each for males and females having available standing height and sitting height measurements were used. Sub-ischial height was calculated as the difference between standing height and sitting height. Sample sizes vary from 14 to 295 individuals. Twenty-six groups were analyzed. Ages of the subjects were truncated to include only those individuals between the ages of 20-40. Only those individuals reporting as full-blooded were utilized. This study included 1,958 males and 1,082 females.

The groups utilized from inland North America were the Apache, Cherokee, Chippewa, Choctaw, Cree, Crow, Eskimo, North Carolina Cherokee, Ojibwa, Paiute, Shushwap, San Luis Rey, Sioux, and Thompson. The American groups of the Northwest Coast were the Klamath, Kwakiutl, Lillooet, Makah, Micmac, and Tsimshian. The Siberian groups consisted of the Aiwan, Evenki, Itelman, Koryak, Maritime Chukchi, and Reindeer Chukchi.

Review of Relevant Statistical Procedures

Statistical applications addressing sexual dimorphism have been varied. Most studies expressed sexual dimorphism in terms of the male/female ratio. A problem with this method is that the ratio fails to consider the male and female overlap in the two distribution curves (Bennett, 1981). Bennett (1981) outlined a statistical procedure that expresses the degree of dimorphism without male/female overlap. Individuals whose measurement values would classify them as the opposite sex are eliminated. This procedure can be used with just mean and standard deviation information (summary statistics) and does not require the raw data, which is often not available. The percentage of areas remaining under the male and female distribution curves is used to determine the degree of sexual dimorphism in a population. These percentages are then compared between populations using a t-test based on arcsin transformations of the percentages from each population. Using such a procedure, Bennett examined anthropometric variates among Eskimos from N.W. Alaska and the Hadza from Tanzania, and found that extremity measurements may be especially useful for evaluating degrees of sexual dimorphism.

Chakraborty and Majumder (1982) are critical of Bennett's method, explaining that Bennett assumes normality of the two (male and female) distributions with equal variances, and this assumption is not often met in practice. Secondly, Bennett's procedure of obtaining the threshold value by taking a simple average of the means of the two sex groups is not true in general, when the groups exhibit different variances. Chakraborty and Majumder suggest that to avoid problems of overemphasizing sex differences, calculate the total area of nonoverlap between the phenotypic distributions of males and females and use it as a measure of sexual dimorphism.

Eveleth (1975) performed regressions of the difference between average male and female stature on the midpoint between the male and female means. According to Eveleth (1975), the use of ratios in studies of sexual dimorphism in stature does not give precise information at the lower and upper ends of the range of heights and could lead to misinterpretation. Eveleth assessed the degree of sexual dimorphism in a group of populations by comparing the differences between male and female mean height. Linear regression is applicable because it allows for more accurate comparisons of different groups with widely different stature means and eliminates the bias caused by differences in overall stature (Eveleth, 1975).

Cheverud and Leutenegger (1986) measured sexual dimorphism in body size as the logarithm of the difference between male and female weights. This method was preferred to a procedure based on ratios. According to Cheverud and Leutenegger (1986), the use of ratios is not preferable for statistics involving linear combinations, as they do not control for size unless the regression of numerator on denominator has a slope of one.

A Tale of Two T-Tests

Greene (1989) outlined the use of a t-test to evaluate the differences in metric sexual dimorphism between populations. It is based upon the differences between distributions. The test is practical because it can be used with summary statistics and is similar in form to sexual dimorphism among groups. However, univariate strategies lack the ability to examine variable interaction and to identify patterned differences in dimorphism within and between human groups (van Vark et. al., 1989). Therefore, I applied a multivariate extension of the test to my data such as the MANOVA procedure with an interaction previously used by Key and Jantz (1981) to test for site*sex differences in Arikara crania. In this study, the interaction is group*sex. The interaction term tests for sex differences by group.

Statistical Analysis

The statistical test used was a two-level analysis of variance (ANOVA) with a group*sex interaction, which tests for sexual dimorphism between groups, as outlined by Konigsberg (1991). A multiple analysis of variance (MANOVA) was also performed using the logarithms of sitting height and sub-ischial height to determine which component of stature contributes more to sexual dimorphism. The data were logarithmically transformed to remove the association between the standard deviations and the magnitude of their means.

The dependent variables for this study were standing height (stature), sitting height, and sub-ischial height. Sub-ischial height is defined as the difference between stature and sitting height and is a measure of leg length. According to Hall (1978), sub-ischial height is important to include in a study of sexual dimorphism in height because it is a measure that excludes the vertebral column, which is subject to age-related decrement. The independent variables were group and sex.

Statistical treatment of the data consisted of analyses of variance (ANOVA and MANOVA) using the SAS software for statistical analysis (The SAS Institute Inc., 1985). The SAS program used was designed for unbalanced data (male and female sample sizes were not equal). The analysis of variance (ANOVA) was performed to determine if there was a significant difference in standing height, sitting height, and sub-ischial height sexual dimorphism among the groups sampled. The ANOVA was performed on both logarithmically-transformed data and raw data. An F-test was used to determine significant differences in sexual dimorphism among the groups. The level of significance for the null hypotheses was .05.

The following null hypotheses were tested:

Ho1: There is no standing height sexual dimorphism difference in North American groups and Siberian groups.

Ho2: There is no sitting height sexual dimorphism difference in North American groups and Siberian groups.

Ho3: There is no sub-ischial height sexual dimorphism difference in North American groups and Siberian groups.

A multiple analysis of variance (MANOVA) was performed to determine the effects of sitting height and sub-ischial height on sexual dimorphism, as outlined by Franciscus and Long (1991) in their study of nose shape variation. A second analysis was performed using logarithmically transformed data.

Sitting height and sub-ischial height (leg length) are components of stature. The question addressed by the MANOVA is whether intrinsic variation in sitting height is greater than intrinsic variation in sub-ischial height (leg length). Intrinsic variation refers to variability that is not dependent on the magnitude of the mean, or the scale of measurement (Franciscus and Long, 1991). The statistic commonly used to measure intrinsic variability is the coefficient of variation (Vx = s/Xm, or 100 x Vx). This study uses the variance of the logarithmically transformed variates S^2_{lnx} as used by Franciscus and Long (1991). According to Franciscus and Long (1991), S^2_{lnx} is a close approximation of $(Vx)^2$; an examination of the coefficients of variation would lead to the same qualitative results. Franciscus and Long (1991) state that there are two important statistical limitations on the coefficient of variation that can be overcome using S^2_{lnx}. First, when statistically computing two or more coefficients of variation, it must be assumed that they were computed on two independent sets of variates. This is not true for my data since my measurements of sitting height and leg length were taken on the same individual. Secondly, the coefficient of variation is intended to measure intrinsic variation within a single population, but I am interested in intrinsic variation within and among populations. S^2_{lnx} is easily partitioned into within and among population components (as are all variances).

CHAPTER 4

RESULTS AND DISCUSSION

Results

Univariate and Multivariate statistical analyses were performed to determine significant differences in sexual dimorphism among the groups sampled. The results for both the logged and unlogged analyses were very similar. The overall tests of the main effects and interaction for the logged univariate analysis are given in Table 1.

In both the logged and the unlogged ANOVA's, there was significant sexual dimorphism (group by sex interaction) between groups for standing height, sitting height, and subischial height. The effects due to sex and group were also highly significant. This suggests that there is overall heterogeneity among the groups represented in the sample. The group*sex interaction is highly significant for the three variables, suggesting group differences in sexual dimorphism. In both the logged and unlogged MANOVA's, subischial height and sitting height sexual dimorphism were also highly significant.

Table 1. Analysis of variance on log transformed data. Test for group*sex interaction.

Variable	**SS**	**DF**	**MS**	**F**	**P**
Sitting Height					
Model	4.7518	51	0.0931	58.9	0.0001
Error	4.7266	2988	0.0016		
Sitting Height	**TypeIII SS**	**Df**	**MS**	**F**	**P**
Group	1.2177	25	0.0487	31.01	0.0001
Sex	1.0945	1	1.9045	1204.01	0.0001
Group*sex	0.0124	25	0.0049	3.14	0.0001
Sub-ischial Height					
Model	13.4625	51	0.0264	93.23	0.0001
Error	8.46	2988	0.0028		
Sub-ischial Height	**TypeIII SS**	**Df**	**MS**	**F**	**P**
Group	5.0019	25	0.2001	70.66	0.0001
Sex	3.651	1	3.651	1289.42	0.0001
Group*sex	0.0166	25	0.0066	2.34	0.0002

The group mean standing, sitting, and sub-ischial heights for males and females are presented in the Appendix.

The group sexual dimorphism measurements for standing height, sitting height, and sub-ischial height are presented in Table 2. The group exhibiting the highest degree of sexual dimorphism for standing height was the Apache and the lowest was the Maritime Chukchi. The group with the highest degree of sexual dimorphism for sitting height was the Crow and the lowest was the Aiwan. The group with the highest degree of sexual dimorphism for sub-ischial height was the Ojibwa and the lowest was the Lillooet.

Figures 1 and 2 present plots of sitting, and sub-ischial height sexual dimorphism for the groups sampled. The y axis represents sexual dimorphism for height, from low to high dimorphism (male minus female measurements). The x axis represents measurement size from small to large (male plus female measurements). A comparison of the two plots shows that sitting height sexual dimorphism is more variable than sub-ischial height dimorphism.

Table 2. Sexual Dimorphism (M-F difference) for height measurements.

Group	Standing	Sitting	Sub-isch.
Mchuk	91	35	57
Klamath	93	34	54
Lillooet	93	58	35
Koryak	99	40	58
Thompson	101	42	58
Aiwan	103	28	74
Kwakiutl	106	49	57
Itelman	109	48	61
Evenk	110	60	49
Reinchuk	110	40	65
Eskimo	114	47	66
Sioux	118	62	56
Cree	125	67	58
Shushwap	125	59	66
Makah	126	59	67
Tsimshia	127	44	83
NCCherokee	130	59	72
Cherokee	132	64	68
Paiute	133	64	69
SanLuis	135	57	77
Chippewa	136	57	78
Choctaw	137	42	95
Ojibwa	137	40	96
Crow	139	75	64
Micmac	144	70	74
Apache	145	69	74

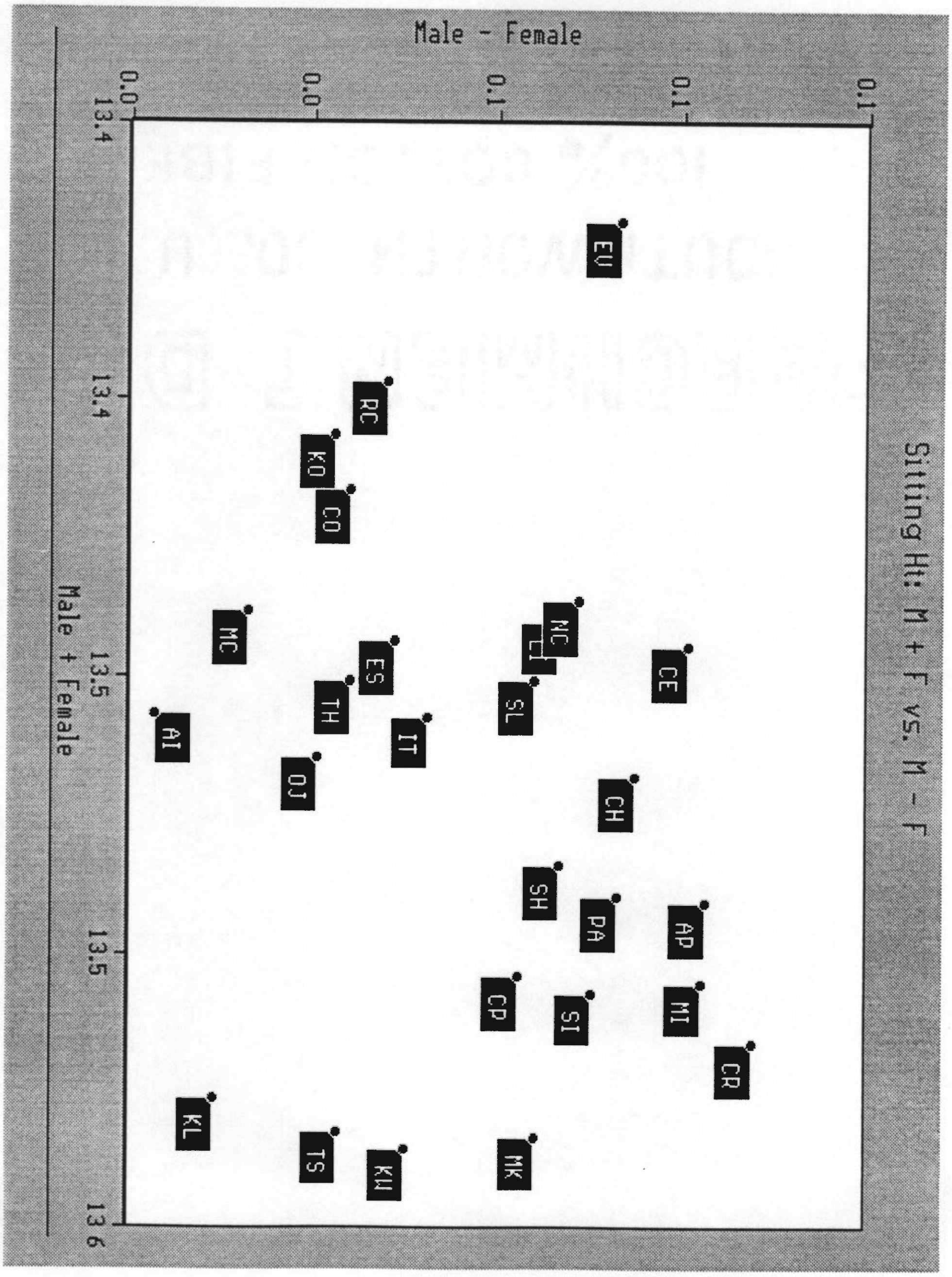

Figure 1. Standing height sexual dimorphism.

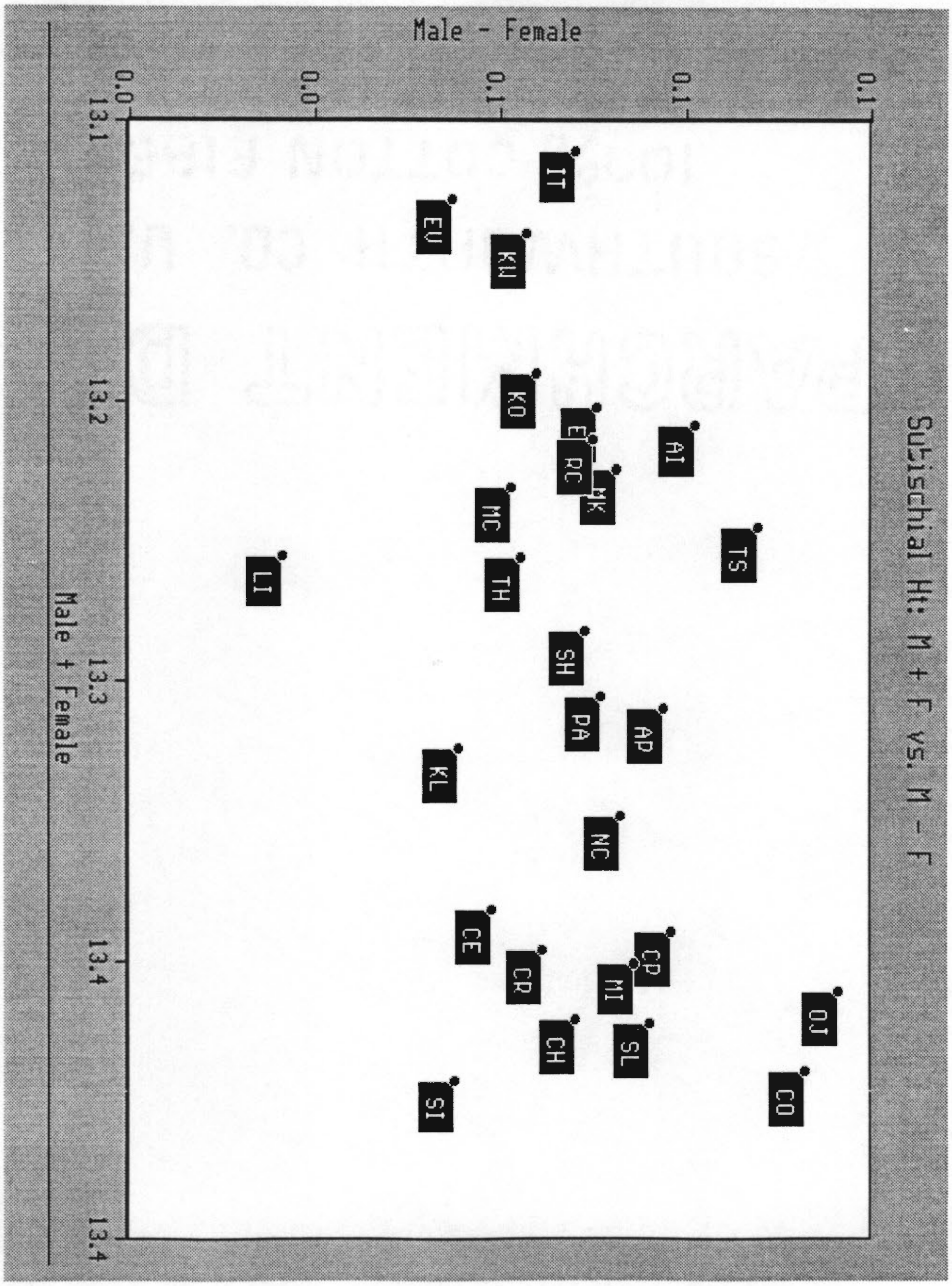

Figure 2. Sub-ischial height sexual dimorphism.

The groups of the Northwest Coast of North America exhibited a pattern of low sexual dimorphism as compared with the inland North American groups sampled. Further, the Northwest Coast pattern of low dimorphism is similar to a pattern of low dimorphism for the Siberian groups.

Intrinsic Variation

Variance-covariance matrices among and within groups (logged) were computed by sex as presented in Tables 3 and 4. Intrinsic variation in sitting height among populations is less than intrinsic variation of leg length. A positive covariance among groups but not within groups suggests some common process affecting sitting height and leg length in the populations. The within-group variation in leg length is about twice that of sitting height in females and is also larger in males.

The covariance/correlation matrices show little correlation between sitting height and sub-ischial height within groups for both the male and female samples. The lack of correlation shows that within groups, sitting height and leg length vary independently of one another.

Table 3. Log Transformed Matrices.

Males

Within-Groups Covariance Matrix

	Sitting	**Sub-ischial**
Sitting	0.00166	0.00001
Sub-ischial	0.00001	0.00283

r = .0046

Among-Groups Covariance Matrix

	Sitting	**Sub-ischial**
Sitting	0.05066	0.02759
Sub-ischial	0.02759	0.15912

r = .3073

Table 4. Log Transformed Matrices.

Females

Within-Groups Covariance Matrix

	Sitting	**Sub-ischial**	
Sitting	0.00145	-0.0001	r = -.0208
Sub-ischial	-0.00001	0.00284	

Among Group Covariance Matrix

	Sitting	**Sub-ischial**	
Sitting	0.01891	0.00986	r = .1555
Sub-ischial	0.00986	0.0793	

The covariance/correlation matrices showed a correlation between sitting height and sub-ischial height among groups for both the male and female samples.

The greater intrinsic variation in leg length relative to sitting height could mean:

1. Leg length is environmentally more sensitive.
2. Measurement error in leg length is greater.
3. Leg lengtih is genetically more variable.

To determine the contribution of genetic versus environmental effects on the variables, estimates of heritability were made based on Konigsberg and Ousley's (1995) study of five Amerindian groups from the Boas data base. For estimation of the heritability (h^2) of a measurement based on one parent and one offspring, it may be shown that this is given by the relation

$$h^2 = \frac{2 Cov_{OP}}{Var_P} = 2\beta_{OP}$$

where ^{cov}OP denotes the covariance between offspring and one parent, and var_P denotes the variance of the parents. The term βOP therefore is simply the regression coefficient of offspring on parent (van Vark and Howells, 1984).

The estimates of the heritability for standing height, sitting height, and sub-ischial height, calculated according to the above formula are given in Table 5. Estimates of phenotypic correlation, environmental correlation, and genetic correlation are given.

Leg length and sitting height coavariances were estimated as:

$Var_{LL} = Var_{HT} + Var_{SH} - 2COV_{HT\ SH}$ and

$Var_{HT} = Var_{SH} + Var_{LL} + 2COV_{SH\ LL}$

$Cov(SH, LL) = Cov(SH, HT) - Var(SH)$

Where LL is leg length, SH is sitting height, HT is standing height.

It was determined that 40 percent (.3955) of the variance of standing height in selected North American groups (Boas data) is due to genetic factors. Fifty-four percent (.5365) of the variance of sitting height is due to genetic factors. Twenty-eight percent (.2802) of the variance of leg length is due to genetic factors.

Table 5. Heritability .

	Genetic Var	Environ. Var	Phenotyp. Var	h2
Standing Height	0.3955	0.512	0.9075	0.4358
Sitting Height	0.5365	0.3677	0.9042	0.5933
Sub-Isch Height	0.2802	0.2883	0.5685	0.4929

Variance-covariance matrices

Genetic

	Sitting	**Sub-isch**	
Sitting	0.5365	-0.2106	r = -.5432
Sub-Isch	-0.2106	0.2802	

Environment

	Sitting	**Sub-Isch**	
Sitting	0.3677	-0.072	r = -.2211
Sub-Isch	-0.072	0.2883	

Phenotypic

	Sitting	**Sub-Isch**	
Sitting	0.9042	-0.2826	r = -.3942
Sub-Isch	-0.2826	0.5685	

Heritability estimates from five of the North American groups suggest that leg length is more susceptible to environmental influences than standing height or sitting height.

These data suggest that the major part of variation for sitting height is due to additive polygenic inheritance, but that environmental factors make some contribution to the variation. A major part of the variation in leg length is due to measurement error but additive polygenic inheritance makes some contribution to the variation. A major part of variation in standing height is also due to measurement error, although less so than in leg length.

The Cormic Index

Many populations show a tendency toward a particular body form. Climate can affect body proportions as illustrated by Bergmann and Allen. A useful tool for comparison is the *cormic index,* a ratio obtained by dividing sitting height by standing height (Molnar, 1975). A ratio of 50 would indicate the legs and trunk plus head were approximately the same length. Many Chinese populations as well as groups of American Indians and Eskimos have cormic indices as high as 54 percent, indicating relatively long trunks and short legs (Molnar, 1975).

Cormic indices for the groups sampled have been calculated and are presented in Table 6. The cormic indices for my samples range from an average low of 50 for the Choctaw to an average high of 55 for the Kwakiutl. The average index for the North American groups was 53. These indices indicated relatively longer trunks and short legs for all of the groups except an index of 49 for Choctaw males, who have slightly longer legs than trunks, and the Choctaw who, with an average index of 50, have trunks and leg measurements of approximately equal length. Kwakiutl females had the highest index at 55, thus having the longest trunks and shortest legs in the sample.

In the univariate analyses of the two sexes, it was determined that for both sexes, there is slight positive covariation among groups, but there is no covariation within groups for the two variables of sitting height and sub-ischial height.

Table 6. Cormic indices, from lowest to highest.

Group	Index
Choctaw	50
Ojibwa	51
Cherokee	51
Cree	51
Sanluis	51
Sioux	51
NCCherokee	52
Chippewa	52
Crow	52
Micmac	52
Apache	53
Klamath	53
Koryak	53
Mchuk	53
Paiute	53
Reinchuk	53
Thompson	53
Aiwan	53
Lillooet	53
Eskimo	53
Evenki	53
Shushwap	53
Tsimshia	54
Itelman	54
Makah	54
Kwakiutl	55

It appears that selection favors overall sexual dimorphism. Females are more similar over groups and males are more variable. The among-groups covariance matrix figures for males were higher than for females, suggesting that males show a higher degree of variation with respect to sitting height and leg length. Thus, females seem to be experiencing stabilizing selection.

The Peopling of North America:
The Northwest Coast/Siberia Connection

The consensus is that the New World was originally populated by several migrations of peoples from northeast Asia (Neumann, 1952). Various estimates of the initial migration of Asiatic peoples into the New World across the Bering land bridge range from 30,000 years ago to 12,000 years ago (See Irving, 1985; Haynes, 1969). The Bering land bridge that connected Siberia and Alaska during Early Wisconsin Time, as early as 35,000 years ago and as late as 11,000 years ago, was over 1,000 miles wide (Laughlin, 1963). Turner (1987) states that the Northwest Coast groups are theorized to have descended from the 9,000 to 10,000 year-old Paleo-Arctic tradition bearers of Alaska and their 12,000+- year-old counterparts in Siberia.

In Turner's (1985) dental analysis of Native American origins, he states that the Greater Northwest Coast Indians have the lowest amount of internal variation. Turner theorizes that the cultural and environmental characteristics of the Northwest Coast peoples may have encouraged much internal migration and gene flow. Turner explains that this could arise from mating practices (exogamous clans), slavery practices, and high mobility along the Pacific Coast in large boats. Secondly, the low variation suggests a relatively recent common ancestor by either relatively recent entry into the Northwest Coast, or via a rapid expansion from a single ancestral group some time after arrival (a possibility Turner does not favor). A third explanation is that the founders of the Northwest Coast region were so few that the gene pool for the dental loci was much less than that of the other North American groups.

A three-wave migration theory is currently popular and is based upon dental evidence, blood allele frequencies, and linguistic evidence (see Greenburg et.al., 1986; Zegura, 1975). The linguistic analysis has discovered only three linguistic divisions (hence, three migrations). The oldest is identified as Amerind, which centers further to the south than the others and shows greater internal differentiation.

The second is identified as Na-Dene and has deeper internal divisions. Aleut-Eskimo is identified as the most recent migration. It is geographically more peripheral than Na-Dene. This would be the group including the ancestors of the Northwest coast. Dates for the Aleut-Eskimo divergence have ranged from 2,900 to 5,600 B.P. and tend to cluster about 4,000 B.P. (Greenburg et. al., 1986).

The dental evidence is said to correspond with the linguistic evidence (Greenburg et. al., 1986). According to Turner (1987), the Amerind dental pattern is similar to that of Northeast Asians, and is called "sinodont," a Northern-type pattern. There are three dental subpatterns in North America with culture area and language correspondences: American Indian, Greater Northwest Coast Indians, and Aleut-Eskimo. Turner (1987) states that the sinodont dental pattern of native Americans could possibly (albeit weakly) be explained as a chance genetic linkage when selection favored a cold-adapted somatotype. Turner explains that, in the arctic-like conditions of late Pleistocene northeastern Siberia, a cold-adapted somatotype could evolve by selection for neotenous adults. Mongoloid infantile features retained into adulthood include low sexual dimorphism and short arms and legs.

There are currently two competing theories proposed based on the archeological evidence for the peopling of the New World (Steele and Powell, 1992). The first is more common and theorizes that the first Americans, who became makers of Clovis projectile points, entered Beringia about 14,500 years ago and appeared south of the Canadian ice sheets border about 11,500 years ago (e.g., Greenburg et. al., 1986). The alternate theory proposes that the first Americans arrived south of the ice sheets some time before the Clovis peoples, carrying with them a pebble tool tradition similar to the Lower Paleolithic assemblages of Asia, which are difficult to recognize in the archaeological record (Steele and Powell, 1992).

According to Turner (1987), the Northwest Coast groups appear to have entered the New World after the other two groups (Indians and Aleut-Eskimos), or could have actually formed as a hybrid of the two groups, this becoming a two-wave migration. Turner's dental analysis and Spuhler's (1979) analysis both concluded that internal divergence seems to be due to genetic drift in the America's as no pattern of regional variation suggests the effects of much selection after arrival in North America.

Anthropometric studies place the Northwest Coast groups as generally biologically closer to Siberians and Eskimos than other Amerindians (Ousley, 1995). Thus, a more recent migration into the New World is suggested for the Northwest Coast groups. It is probable that the sharpness of metric resemblance to Asian groups fades with the number of generations in the America's (Newman, 1953).

Controversy persists as to the scenario of the peopling of the New World. Szathmary (1979) has proposed successive waves of migration into the New World. The perception of Eskimo biological uniqueness has been challenged (see Szathmary and Ossenberg, 1978; Szathmary, 1979). The agreement among data sets of the Greenburg et. al., (1986) study has been challenged (see Comments section of Greenburg et. al., 1986). Thus, the history of New World migration is generally speculative.

Discussion

This study finds that the patterning of low sexual dimorphism in Northwest Coast Amerindian groups is similar to a patterning of low dimorphism in Siberian groups. While all the North American groups are thought to have a common ancestor with Siberian groups, it appears that the Northwest

Coast and Siberia have a more recent ancestry than the other North American groups. The climates of the Northwest Coast and Siberia are dissimilar, making it appear that climatic adaptation is not the common factor in their patterns of low dimorphism. However, it is possible that climate may be involved. Due to a more recent ancestry of Northwest Coast groups and Siberian groups, both exhibit phenotypic characteristics of adaptation to a cold climate. A longstanding adaptation to cold is evident in the morphology of the Siberian groups, who have short limbs relative to trunk height. The Northwest Coast groups have not been in the New World long enough for adaptation to a different climate to be evident. Thus, they exhibit a cold-adapted morphology such as shorter limbs relative to trunk height. They also exhibit a pattern of reduced sexual dimorphism as do the Siberians. It is possible that a long-term adaptation to cold has produced shorter mean height measurements for both sexes, perhaps with a greater reduction in heights for the males, who are more variable in their height measurements than females, and low sexual dimorphism has resulted. The amount of time necessary for sexual dimorphism to evolve a low pattern in these groups was sufficient, but not enough time in the New World has passed for a different pattern to emerge, thus, a similar patterning still exists between them.

The inland North Amerindian groups are more variable in their patterns of sexual dimorphism, and display a different pattern than that of the Northwest Coast and Siberian groups due to a longer existence in the New World. A significant amount of time inhabiting a new climate has passed for selective pressures to exert a change in patterns of sexual dimorphism for these inland groups. A more similar genetic makeup for the Northwest Coast groups and Siberian groups is also partly responsible for their similarities in low dimorphism. The inland groups have been apart from the common ancestor long enough for selection to cause phenotypic and genetic changes.

In this study, stabilizing selection appears to be a prominent factor in sexual dimorphism. Stabilizing selection maintains the type of a species by the elimination of individuals who are not adequate to the requirements of its environment and way of life (Brues, 1977). The results of this study suggest that males are more variable in measures of height than females, while females are more stable.

A multiwave migrational theory of the peopling of the New World is supported by my examination of patterns of sexual dimorphism in North America. Different migrations at different time periods have obviously taken place as climatic variations alone cannot explain the differing patterns of dimorphism of the N.W. Coast groups relative to the inland groups. As stated above, the Siberian climate is cold and harsh; thus, it can be expected that phenotypically, cold-adaptation is reflected in their morphology. The Northwest Coast is a temperate region, yet the Northwest Coast groups seem to be morphologically more cold-adapted. The similarity of cold-adaptation morphology in the Northwest Coast groups and Siberian groups points to a more short-term existence of the Northwest Coast groups in the New World, as the effects of a more temperate climate have not affected their phenotype as much as in the inland groups. Their pattern of sexual dimorphism is not significantly different from that of the Siberian groups, but is different from that of the inland North American groups. While the population mean in stature may change in a new environment, a much greater amount of time is needed to affect the degree of sexual dimorphism in a population. A more recent Northwest Coast relationship to Siberia than the inland North American groups is suggested by the data.

The differing degrees of sexual dimorphism among the North American groups may suggest a lack of selective pressures acting on dimorphism, or that there has not been enough time for dimorphism equilibrium to evolve. The similar patterning of the Northwest Coast groups and the Siberian groups may be due to a similar genetic makeup or a longstanding adaptation to their common environment before New World migrations, or a combination of both. The low dimorphism of both the groups could be a result of cold-adaptation, which in this case, reduced mean heights of both sexes and thus a pattern of low dimorphism emerged. I suspect a combination of genetic factors and climatic factors are responsible for the patterns of sexual dimorphism discovered in this study. Rogers and Mukherjee (1991) state that a great deal of time is necessary for the evolution of sexual dimorphism. While group means in height may change over a short period of time, much more time is needed for group averages in sexual dimorphism to emerge. Forces such as marriage systems, settlement patterns, nutritional status, climate, and division of labor, exert selection pressures to effect a change in growth patterns. Most of these forces have not been stable for long enough periods of time to effect a change in sexual dimorphism. Climate is one force that does remain fairly constant over a very long period of time. Therefore, it is reasonable that climatic adaptation would have an influence on patterns of sexual dimorphism.

My analysis supports the findings of Tobias (1975), Stini (1975), Hamilton (1975), and Hall (1978) in that variation among groups is greater in males. This study suggests that among groups, females are experiencing stabilizing selection, whereas males are more variable in measures of height.

CHAPTER 5

CONCLUSION

Studies of sexual dimorphism have sought to explain differing patterns by examining relationships between dimorphism and other variables, such as climate, nutritional status, settlement patterns, division of labor, and marriage systems. While these variables can undoubtably affect growth patterns, to affect size on a population-wide basis, a prolonged amount of time is necessary for significant size differences to occur between the sexes. Marriage systems, nutritional status, divisions of labor, and settlement patterns were not stable over long enough periods of time to allow for the evolution of sexual dimorphism. "Sexual dimorphism evolves so slowly that we cannot expect a close fit between it and the ecological and social circumstances of local populations" (Rogers and Mukherjee, 1991). Secondly, separating the genetic aspects from environmental factors is difficult. It is possible that more than one mechanism may be operating at once to produce sexual dimorphism. One would need to identify these factors and the role each plays in sexual dimorphism.

The reduced dimorphism shared by the Northwest Coast groups and Siberian groups suggest a more recent ancestry than the inland North American groups. This is consistent with multiwave migrational theories on the peopling of the New World.

The temperate climate of the Northwest coast does not fit with their cold-adapted physiology, pointing to the likelihood that the Northwest Coast groups have not been in the New World long enough for climatic adaptation to effect a change in morphology. Unlike the environmental factors of nutritional status, settlement type, division of labor, and marriage systems, climate is a very long term factor. Sexual dimorphism could have evolved as a result of long-term climatic selection in Siberia. Sexual dimorphism may be another aspect or result of cold-adaptation where both male and female mean heights were reduced. It has been suggested in other studies that male growth patterns are more susceptible to harsh environmental conditions. Siberia is known to have a harsh environment. Results of this study suggest that males are more variable in height measurements, and females are more stable. Perhaps the mean height of males has reduced to a point that is similar to the female mean and low sexual dimorphism is the result.

As the Northwest Coast had adequate nutrition, a theory based upon poor nutrition does not explain their patterns of sexual dimorphism. Northwest Coast groups arrived later than the inland North American groups and due to a certain degree of isolation were relatively not as varied as other North American groups.

This study suggests that the differences in sexual dimorphism patterns in North America and the similarities in patterning of the N.W. Coast groups and Siberia groups are a reflection of the involvement of a combination of genetic and environmental factors. Stature, or any other body measurement that represents a permanent skeletal dimension (i.e., not subject to short-term nutritional effects) will have a heritability of .8, indicating a four to one predominance of genetic factors over environmental ones (Cavalli-Sforza and Bodmer, 1971; Brues, 1977). In this study, it is not stature that determines sexual dimorphism as much as leg length, which is highly susceptible to environmental influences. A pattern of low dimorphism for both the Northwest Coast groups and Siberian groups may have resulted from cold-adaptation in Siberia before the Northwest Coast groups migrated to the New World.

Sexual dimorphism is a complicated issue. One explanation does not apply universally. A multitude of causes and circumstances can produce sexual dimorphism. Important to consider are the effects of genetic makeup and climatic adaptations. These are mechanisms which exist long-term, thus allowing the necessary time frame for the evolution of differing patterns of sexual dimorphism.

Summary and Things to Consider

1. Genetic factors partially explain the variation in patterns of sexual dimorphism.

2. Patterns of sexual dimorphism need a great amount of time to evolve. Marriage systems, nutritional status, settlement patterns, and divisions of labor are variable over time. Climate is a factor that can be implicated in the patterning of sexual dimorphism because climate is a factor that is relatively stable over long periods of time.

3. Extremities (in this case leg length) are good for assessing sexual dimorphism (see Greulich 1976, also, Bennett, 1981), but leg length is also highly susceptible to the environment.

4. Females are more similar over groups and males are more variable, suggesting that females are experiencing stabilizing selection.

5. Cold-adaptation may partially explain a pattern of low dimorphism for the Northwest Coast and Siberian groups. This is a subject for further study. Future studies should consider the possibility of selection for larger females to accommodate larger infant head sizes (at birth) in cold climates as another cold-adapted feature that is reflected in low sexual dimorphism.

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APPENDIX

Standing Height - Males

Group	Mean	Std Dev	Min
Aiwan	1627.19	44.08	1535
Apache	1693.89	58.26	1552
Cherokee	1713.12	51.82	1604
Chippewa	1719.68	55.05	1578
Choctaw	1699.57	47.94	1595
Cree	1687.01	51.18	1554
Crow	1728.99	65.28	1523
Eskimo	1626.77	62.46	1518
Evenki	1570.58	61.38	1402
Itelman	1602.27	49.41	1470
Klamath	1684.68	50.89	1570
Koryak	1598.79	48.03	1490
Kwakiutl	1642.83	66.85	1478
Lillooet	1628.66	59.13	1489
Makah	1675.94	41.61	1602
Mchuk	1620.73	65.47	1495
Micmac	1728.89	45.27	1650
NCCherokee	1675.51	57.61	1547
Ojibwa	1711.77	65.45	1545
Paiute	1685.52	62.47	1514
Reinchuk	1607.61	61.29	1454
Sanluis	1707.91	62.51	1570
Shushwap	1671.81	47.64	1540
Sioux	1729.31	56.41	1541
Thompson	1637.89	58.26	1477
Tsimshia	1682.73	49.15	1584

Sitting Height - Males

Group	**Mean**	**Std Dev**	**Min**
Aiwan	850.47	27.13	805
Apache	886.45	30.51	806
Cherokee	874.07	39.51	803
Chippewa	885.51	38.33	699
Choctaw	840.86	33.22	748
Cree	865.42	29.01	802
Crow	899.91	34.92	721
Eskimo	855.46	55.57	616
Evenki	830.35	29.31	751
Itelman	861.27	31.45	715
Klamath	883.49	39.94	761
Koryak	836.31	35.84	711
Kwakiutl	895.11	40.78	769
Lillooet	859.02	36.53	778
Makah	840.06	26.89	839
Mchuk	846.51	38.36	786
Micmac	893.15	38.37	790
NCCherokee	857.75	29.34	785
Ojibwa	860.19	32.85	792
Paiute	882.75	33.89	790
Reinchuk	834.09	35.36	760
Sanluis	863.43	52.32	690
Shushwap	877.81	28.31	803
Sioux	889.49	33.74	800
Thompson	855.42	33.31	765
Tsimshia	890.91	36.38	730

Sub-ischial Height - Males

Group	Male mean	Std Dev	Min
Aiwan	776.72	36.08	712
Apache	807.44	41.93	700
Cherokee	839.05	37.74	741
Chippewa	834.17	41.41	726
Choctaw	858.71	42.78	748
Cree	821.58	43.43	709
Crow	829.09	46.03	728
Eskimo	771.31	64.86	678
Evenki	740.23	44.02	651
Itelman	741.01	35.01	670
Klamath	801.19	47.61	684
Koryak	762.48	32.48	669
Kwakiutl	747.72	49.09	649
Lillooet	769.64	40.45	710
Makah	777.22	27.63	705
Mchuk	774.22	43.31	695
Micmac	835.74	38.89	764
NCCherokee	817.74	42.41	703
Ojibwa	851.58	55.22	733
Paiute	802.77	42.42	700
Reinchuk	773.52	46.62	677
Sanluis	844.49	51.68	758
Shushwap	794.01	36.44	727
Sioux	839.81	45.28	707
Thompson	782.47	43.66	661
Tsimshia	791.83	44.74	702

Standing Height - Females

	Mean	**Std Dev**	**Min**
Aiwan	1523.96	48.55	1422
Apache	1549.21	52.74	1417
Cherokee	1580.96	66.31	1473
Chippewa	1584.35	45.92	1463
Choctaw	1563.09	44.76	1466
Cree	1561.76	59.13	1413
Crow	1589.93	47.53	1485
Eskimo	1512.89	54.96	1386
Evenki	1460.91	37.79	1377
Itelman	1492.99	48.13	1400
Klamath	1596.53	49.92	1450
Koryak	1499.54	44.03	1380
Kwakiutl	1536.73	43.52	1457
Lillooet	1536.43	40.11	1433
Makah	1550.41	41.74	1470
Mchuk	1529.36	62.81	1412
Micmac	1585.11	55.39	1462
NCCherokee	1544.72	48.46	1444
Ojibwa	1575.46	77.16	1360
Paiute	1552.89	41.27	1464
Reinchuk	1498.29	49.79	1452
Sanluis	1573.45	58.81	1450
Shushwap	1546.75	41.65	1453
Sioux	1611.19	50.15	1468
Thompson	1536.66	50.32	1352
Tsimshia	1555.88	37.45	1488

Sitting Height - Females

Group	**Mean**	**Std Dev**	**Min**
Aiwan	822.12	29.18	770
Apache	816.55	32.71	726
Cherokee	809.57	29.02	740
Chippewa	828.66	30.81	764
Choctaw	798.81	30.24	749
Cree	798.14	26.61	750
Crow	825.31	31.31	760
Eskimo	808.28	30.99	746
Evenki	770.18	18.31	730
Itelman	812.66	30.67	730
Klamath	849.05	29.54	800
Koryak	795.65	34.34	705
Kwakiutl	845.91	30.22	762
Lillooet	801.23	31.89	710
Makah	898.72	29.37	786
Mchuk	811.86	43.41	735
Micmac	823.05	40.72	740
NCCherokee	798.78	28.98	711
Ojibwa	819.74	34.61	714
Paiute	818.89	23.58	769
Reinchuk	789.51	23.51	740
Sanluis	806.25	31.61	747
Shushwap	818.75	28.11	720
Sioux	827.37	34.11	745
Thompson	812.74	31.26	752
Tsimshia	846.85	24.23	790

Sub-ishial Height - Females

Group	**Mean**	**Std Dev**	**Min**
Aiwan	701.84	36.22	632
Apache	732.66	40.77	651
Cherokee	771.39	52.86	657
Chippewa	755.69	31.87	671
Choctaw	764.29	37.21	677
Cree	763.62	50.22	639
Crow	764.64	40.68	684
Eskimo	704.61	34.41	640
Evenki	690.71	32.41	604
Itelman	680.33	33.91	615
Klamath	747.47	46.45	643
Koryak	703.89	31.89	589
Kwakiutl	690.83	40.25	623
Lillooet	735.21	33.21	674
Makah	710.33	41.11	637
Mchuk	717.51	47.45	647
Micmac	762.05	50.66	662
NCCherokee	745.94	32.35	679
Ojibwa	755.71	64.16	564
Paiute	734.01	28.96	672
Reinchuk	708.79	48.07	661
Sanluis	767.21	41.36	694
Shushwap	728.01	32.24	656
Sioux	783.81	41.56	653
Thompson	723.92	40.69	600
Tsimshia	709.04	37.03	652

VITA

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