CONGENITAL MALFORMATIONS
THE INFLUENCE OF GENETIC AND NONGENETIC FACTORS

Progress Report

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January 1, 1972 - December 31, 1972

PREPARED FOR THE U. S. ATOMIC ENERGY COMMISSION UNDER
CONTRACT NO. AT(11-1)-2013

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Enclosures:

1. Ltr dtd 9/25/72 Hunnicutt/Miller
2. Renewal Proposal (4)
3. Financial Statement of Estimated Costs
4. Budget
5. Proposed Technical Scope
6. SIE Forms (3)
7. Technical Progress Report No. COO-2013-20, entitled "Congenital Malformations: The Influence of Genetic and Nongenetic Factors" (4)

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ABSTRACT

During the years 1961-1966 and 1969-1972, research has been carried out to determine the importance of genetic and nongenetic factors for specific congenital malformations in man. This work has been supported by the U. S. Atomic Energy Commission. Before the etiological role of mutation can be evaluated for congenital malformations, it is necessary to obtain this information. During the present contract period (1972), data have been collected on (1) the symmetry of dermatoglyphic patterns in children with specific malformations, (2) the frequency of spontaneous abortions in mothers who have produced a child with spina bifida cystica, and (3) the season of birth of children born with congenital hip disease in Los Angeles, California. A survey was also initiated of the world literature to find pedigrees of Type I syndactyly; the purpose is to gain insight into the unusual sex ratio for this anomaly. During the contract period negotiations were made to obtain approval for a study of congenital hip disease among the Apache Indians in Arizona. The study was finally initiated when approval was obtained during August, 1972. Three manuscripts were also written during the grant period for possible publication.

INTRODUCTION

A research program has been carried out in the Department of Zoology, Arizona State University, Tempe, Arizona during the periods 1961-1966 and 1969-1972, to evaluate the importance of genetic and non-genetic factors for specific congenital malformations in man. This work has been supported in its entirety by the U. S. Atomic Energy Commission. It is apparent that before the etiological role of mutation can be evaluated for congenital malformations it is necessary to obtain this information.

During the first eight months (January 1, 1972 - August 31, 1972) of the present contract period, the primary activities were to continue studies of syndactyly and spina bifida cystica, collect and analyze data on symmetry of dermatoglyphic patterns in children with specific congenital malformations, analyze data and write a paper on polydactyly in American Negroes and Whites, write a manuscript on albinism in the American Indian, write a manuscript on syndactyly in Utah, continue studies on the effect of season of birth on the incidence of congenital hip disease, and initiate studies on congenital hip disease in the Apache Indian of Arizona.

During this period the principal investigator spent in excess of the contracted 100% of two summer months and 10% of the academic year period (9 months) working on the project. During the remainder of the current term (September - December) the principal investigator will devote in excess of 10% of the academic year period to the project.

POLYDACTYLY IN AMERICAN NEGROES AND WHITES

Charles M. Woolf¹ and Ntinos C. Myrianthopoulos²

The data are derived from the Collaborative Study of Cerebral Palsy, Mental Retardation, and Other Neurological and Sensory Disorders of Infancy and Childhood, which is supported by the National Institute of Neurological Diseases and Blindness. The senior author was supported by U. S. Atomic Energy Commission contract AT(11-1)-2013 to Arizona State University.

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Neel [1] brought attention to the fact that even though the total incidence of major congenital malformations may be relatively similar in all large world populations, there are differences among populations in the incidence of specific malformations. Some populations are characterized by a high incidence of a certain type of congenital anomaly. A dramatic example is polydactyly in the American Negro [2 - 7]. About 1.3% of all American Negroes are born with polydactyly; it is about nine times more frequent in the American Negro than in the American White [7]. The occurrence of polydactyly at such a high frequency in the American Negro presents an intriguing problem in population genetics.

Polydactyly is characterized by etiologic heterogeneity [8, 9]. Preaxial polydactyly involving a triphalangeal digit in place of a thumb may show dominant inheritance, while preaxial polydactyly involving duplication of the first digit has a more complex etiologic mechanism. This latter type of polydactyly may show polygenic inheritance. Postaxial polydactyly may be represented by pedunculated postminimus (often in the form of a skin tag), or a partially or fully developed extra ulnar or fibular digit. If the extra fifth digit is well developed and wholly or partially articulated, the condition is referred to as postaxial polydactyly type A. Pedunculated postminimus is referred to as postaxial polydactyly type B. The genetic relationship between

these two types has not been resolved. Sverdrup [10] studied a Norwegian family showing members with both type A and type B postaxial polydactyly. From an analysis of 37 affected members in 6 generations, he noted that affected offspring of individuals with type A possessed either type A or type B, but affected offspring of individuals with type B had only type B. He concluded that a dominant autosomal gene is responsible for type B, while this gene plus genetic modifiers account for type A. Woolf and Woolf [9] encountered two kindreds with members showing type A or type B postaxial polydactyly. In one of these kindreds an individual with type B had children and grandchildren with type A. This pedigree stands as an exception to the hypothesis that a type B parent may only have type B children. It seems evident that the dominant mutant gene segregating in this family may express itself as type A or type B postaxial polydactyly; the difference in expression may be due to modifiers. Other modes of inheritance are present for postaxial polydactyly. It occurs as part of several different genetic syndromes [8, 11], and it is clear that extra fifth digits may be one manifestation of abnormal growth produced by chromosomal imbalance. Postaxial polydactyly is a common feature of trisomy D_1 [12].

Meaningful genetic and comparative incidence studies of polydactyly must take into consideration the various types. It is remarkable that

no published data are available to document which type of polydactyly makes up the bulk of the cases occurring in the American Negro.

This deficiency results from the inadequacy of birth certificates and most medical records in describing dactyly anomalies present in newborns. Anomalies that are phenotypically and etiologically distinct are grouped under the single category of polydactyly in all published incidence data.

The objective of the present study is to present data on the incidence of the various types of polydactyly in the American Negro and White populations and to show that postaxial polydactyly type B (pedunculated postminimus) is the type which has the high incidence in the former population.

PROCEDURE AND RESULTS

Data were obtained from records available at the National Institute of Neurological Diseases and Blindness, National Institutes of Health, Bethesda, Maryland. These records were collected by the Collaborative Study of Cerebral Palsy, Mental Retardation and Other Neurological and Sensory Disorders of Infancy and Childhood [7]. They concern consecutive births (both livebirths and fetal deaths) occurring in 12 different hospitals in the United States: Boston Lying-In Hospital; Children's Hospital of Buffalo; Charity Hospital, New Orleans; Columbia University; Johns Hopkins University; Medical College

of Virginia; University of Minnesota; New York Medical College; University of Oregon; Pennsylvania Hospital; Providence Lying-In Hospital; and University of Tennessee. Polydactyly was present in 344 Negroes and 32 Whites; the approximate denominators were 26,000 Negroes and 26,000 Whites.

The records of all 376 polydactyly cases were hand reviewed. Each case was scored as to ethnic group and sex. Based on comments written in the records by attending physicians, an attempt was made to classify each case as to type of polydactyly (preaxial, postaxial type A, or postaxial type B), location of the anomaly (hands or feet), whether the dactyly anomaly was unilateral or bilateral, and if there were coexisting other malformations. When the description in the records was too vague to allow for accurate classification, the case was scored as unspecified postaxial polydactyly or merely unspecified polydactyly.

The 376 polydactyly cases are presented in Table 1 according to ethnic group, sex, and whether the case was a postaxial or preaxial type of polydactyly. Only one case could not be specified as to type of polydactyly. Another case had both postaxial (hands) and preaxial (feet) polydactyly; this combination of anomalies is occasionally encountered in individuals with polysyndactyly, a rare syndrome often showing dominant inheritance [13, 14]. In both the Negro and White populations, postaxial polydactyly is more frequent than preaxial polydactyly.

Preaxial polydactyly occurs at a similar incidence (0.08 per 1000) in both populations but postaxial polydactyly is over eleven times more frequent in the Negro population (13.08 per 1000 vs. 1.15 per 1000).

In Table 2 the postaxial polydactyly cases are classified as type A and type B. Of extreme interest is the observation that type A has a similar incidence in both the American Negro and American White populations. There were 7 Negroes with at least one well developed fifth digit; 2 of these had polysyndactyly and 1 had Type II syndactyly (synpolydactyly). Six Whites had at least one well developed fifth digit; 2 of these had Type II syndactyly and 1 had a multiple malformation syndrome including syndactyly. Eliminating these syndrome cases from the calculations, leaves 4 Negroes (0.15 per 1000) and 3 Whites (0.11 per 1000) with only type A postaxial polydactyly. It can be concluded from the data shown in Table 2 that the high incidence of polydactyly in the American Negro population, relative to the American White population, is attributed to type B postaxial polydactyly (pedunculated postminimus). A minimum estimate of pedunculated postminimus (with or without associated malformation) for the American Negro is 12.00 per 1000. This is slightly low because of the 21 cases of postaxial polydactyly unspecified as to type A or B. The vast majority of these, if not all of them, are undoubtedly type B. Hence, the inci-

dence of pedunculated postminimus (with or without associated malformation) in the American Negro approximates 12.8 per 1000. A minimum estimate of the incidence of pedunculated postminimus for the American White is 0.85 per 1000. Adding the unspecified cases, which are probably type B, gives an estimate of 0.92 per 1000.

Pedunculated postminimus has been described as one expression of different well-defined syndromes [8, 11]. Cases of pedunculated postminimus with and without associated malformations are present in Table 3. A total of 300 Negroes (11.53 per 1000) with pedunculated postminimus had no associated malformations. Nineteen Whites (0.73 per 1000) were similarly affected. Both incidence values are minimal because of the unspecified cases shown in Table 2. However, they show that pedunculated postminimus without any associated malformation occurs over 15 times more frequently in the American Negro than in the American White. When pedunculated postminimus occurs in an American Negro by itself it is only rarely located in the feet (see Table 4) and is slightly more often bilateral than unilateral in the hands (see Table 5). When it occurs unilaterally in the hands, it is highly probable that the left hand is involved (see Table 6).

DISCUSSION

Frazier [3] and Chung and Myrianthopoulos [7] have demonstrated the biological impact of polydactyly by noting that the total

rate of major malformations is higher in the American Negro than in the American White; however, if polydactyly is excluded from both samples, the total rate is higher in the American White. The results of the present study indicate that pedunculated postminimus is the type of polydactyly which is responsible for this phenomenon. The impact of pedunculated postminimus can be seen from the data published by Chung and Myrianthopoulos [7]. The over-all major malformation rates in the Negro and White groups are 25.5 per 1000 and 17.8 per 1000, respectively. The present study indicates that minimum rates of pedunculated postminimus (without associated malformation) in the Negro and White groups are 11.53 per 1000 and 0.73 per 1000, respectively. Reducing the total rates by these amounts results in total major malformation rates of 13.97 per 1000 for the American Negro and 17.07 per 1000 for the American White.

A question of import is whether pedunculated postminimus should be classified as a major malformation. It is customary to treat this polydactylous condition by simple ligation when the infant is in the nursery or delivery room. It may be sloughed-off in utero. If not treated by ligation, it rarely persists as an intact appendage throughout childhood. The expression in an untreated adult is no worse than a minute bud. Written expressions in the medical records of the diagnosis and treatment manifest the minimal nature of this disorder:

Extra digits. Tabs of skin off lateral side of each fifth finger tied off in delivery room.

Extra digit hanging from little finger of left hand--tied off.

Bilateral accessory fifth fingers attached by pedicle of skin. Nails are present, bones not felt. Tied off with black silk in delivery room.

Bilateral pedunculated postminimus. Tag of skin on left hand, small bud on right hand.

Vestige of extra digit attached to little finger of left hand.

Relative to preaxial polydactyly, postaxial polydactyly type A, the various syndactylies, cleft lip, cleft palate, spina bifida cystica, etc., pedunculated postminimus is a minor malformation which is no more debilitating than an inconspicuous nevus or talipes planus. If pedunculated postminimus is classified as a minor malformation, it can be concluded that the American Negro has a lower rate of major congenital malformations than the American White.

The intriguing problem is the high incidence of pedunculated postminimus in the American Negro. Using the number of polydactyly cases born in the 14 different hospitals as the criterion, there is no obvious incidence difference among Negro subpopulations in different sections of the United States [7]. Furthermore, the etiological role of an exogenous factor endemic to the Negro population in the United States can be negated by the data of Saldanha [15] which demonstrates

that in Sao Paulo, Brazil, polydactyly (all types) occurs significantly more frequently in Negroes than Whites. The biological impact of polydactyly, relative to the total malformation rate, is similar among Negroes in the United States and Brazil. Although evidence is lacking, it is likely that pedunculated postminimus accounts for the high incidence of polydactyly in the Brazilian Negro populations. The occurrence of pedunculated postminimus at a high frequency in Negro populations in different environmental regions suggests that the malformation has a strong genetic component, rather than being due solely to some unknown environmental factor. Published pedigrees demonstrate that in some individuals a dominant gene is responsible for pedunculated postminimus. Ignoring specific syndromes such as polysyndactyly, two general patterns are present. Affected members of some families only have pedunculated postminimus, while affected members of other families may have type A postaxial polydactyly or pedunculated postminimus [8, 9, 16]. Is pedunculated postminimus at a high frequency in the American Negro population because of the high frequency of a dominant gene? If so, it is apparent that this purported allele is not the one that may express itself as type A or type B postaxial polydactyly. If it were, both types should be increased in frequency in the American Negro, which is not the case (Table 2). Furthermore, the purported allele would be one that tends to limit its

expression to the hands, rather than expressing itself in the hands and/or feet (Table 4). Because of reduced penetrance [8, 9], the frequency of individuals carrying this purported allele in the American Negro population would be in excess of the frequency of individuals with the trait. The frequency is obviously too high to be explained by mutation pressure. An individual known to be homozygous for the dominant gene giving pedunculated postminimus has not been identified in any pedigree. The condition may be subviable or lethal. If so, a speculative model to explain the high frequency of the purported allele in the American Negro population would be selection for the heterozygote. One would look to Africa for the environmental condition that bestows the slight advantage on the individuals carrying the allele. Alternative speculative models can be presented. Pedunculated postminimus may show genetic heterogeneity. The type occurring at a high frequency in the American Negro may show polygenic inheritance. Under this model the American Negro and American White populations would differ as to the frequencies of these genes. The corollary would be that these genes have even higher frequencies in the ancestral African populations of the American Negro. Unfortunately, no data are available for populations in Africa. It is of interest that in Brazil, based on limited numbers, mulattoes are intermediate between Negroes and Whites in the incidence of unspecified polydactyly [15]. Other models could

involve pleiotropy or some complex interaction of genetic and extrinsic factors. It is apparent that an understanding of the high incidence of pedunculated postminimus in the American Negro will require, as a prelude, incidence data for various African Negro populations and well-designed genetic studies of this curious anomaly.

SUMMARY

Pedunculated postminimus (postaxial polydactyly type B) has a very high incidence in the American Negro relative to the American White. A minimum estimate of the incidence in the American Negro is 12.00 per 1000 (or 1.2%). A minimum estimate of the incidence of this anomaly by itself, i. e., no associated malformation, is 11.53 per 1000. The corresponding estimates for American Whites are 0.85 and 0.73 per 1000. Preaxial polydactyly and postaxial polydactyly type A have a similar incidence in American Negro and American White populations. When pedunculated postminimus is present in the American Negro, it may be bilateral or unilateral. When unilateral, there is a high probability that it will occur in the left hand. Only rarely are the feet involved.

Pedunculated postminimus accounts for about half of the total malformation rate in the American Negro. If debilitation and extent of surgical correction are the criteria, pedunculated postminimus should be classified as a minor malformation. If so, the total inci-

dence of major malformations is less in American Negro than in the American White populations.

Pedunculated postminimus apparently exhibits genetic heterogeneity. Distribution data suggest that some exogenous factor is not responsible for the high incidence in the American Negro. Incidence data are needed for the ancestral African populations; in addition, studies are needed to determine the genetic mechanisms responsible for this curious anomaly. The high incidence of pedunculated postminimus in the American Negro presents an intriguing problem in population genetics.

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Table 1. Incidence of Postaxial and Preaxial Polydactyly

	American Negro				American White			
Type of Polydactyly	Females	Males	Total	Total Incidence* (per 1000)	Females	Males	Total	Total Incidence* (per 1000)
Postaxial	177	163	340	13.08	19	11	30	1.15
Preaxial	1	1	2	0.08	1	1	2	0.08
Postaxial and Preaxial	1	0	1	0.04	0	0	0	0.00
Unspecified	0	1	1	0.04	0	0	0	0.00
Total	179	165	344	13.23	20	12	32	1.23

* Based on 26,000 pregnancies

Table 2. Incidence of Postaxial Polydactyly Types A and B

Postaxial Polydactyly	American Negro				American White			
	Females	Males	Total	Total Incidence* (per 1000)	Females	Males	Total	Total Incidence* (per 1000)
Type A	1	3	4	0.15	6	0	6	0.23
Type B	165	147	312	12.00	11	11	22	0.85
Types A and B in Same Individual	1	2	3	0.12	0	0	0	0.00
Unspecified	10	11	21	0.81	2	0	2	0.08
Total	177	163	340	13.08	19	11	30	1.15

* Based on 26,000 pregnancies

Table 3. Association of Pedunculated Postminimus With Other Malformations

	American Negro				American White			
Postaxial Polydactyly	Females	Males	Total	Total Incidence* (per 1000)	Females	Males	Total	Total Incidence* (per 1000)
Type B only	160	140	300	11.53	9	10	19	0.73
Type B with syndactyly	2	3	5	0.19	0	1	1	0.04
Type B with other malformation	3	4	7	0.23	2	0	2	0.08
Total	165	147	312	12.00	11	11	22	0.85

* Based on 26,000 pregnancies

Table 4. Postaxial polydactyly type B in the hands and feet.

	American Negro					American White				
Location	Females	Males	Total	Total Incidence* (per 1000)	Proportion of Total	Females	Males	Total	Total Incidence* (per 1000)	Proportion of Total
Hands Only	156	134	290	11.15	0.967	6	8	14	0.54	0.737
Feet Only	1	0	1	0.04	0.003	2	1	3	0.12	0.158
Hands and Feet	2	7	9	0.35	0.030	1	1	2	0.08	0.105
Total	159	141	300	11.53		9	10	19	0.73	

* Based on 26,000 pregnancies

Table 5. Bilateral and Unilateral Cases of Pedunculated Postminimus (No Associated Malformation)

	American Negro				American White			
Malformation	Females	Males	Total	Proportion of Total	Females	Males	Total	Proportion of Total
Unilateral Hands	71	42	113	0.377	5	4	9	0.474
Unilateral Feet	1	0	1	0.003	2	1	3	0.158
Unilateral Hands, Unilateral Feet	0	2	2	0.006	0	0	0	0.000
Unilateral Hands, Bilateral Feet	0	0	0	0.000	0	0	0	0.000
Bilateral Hands, Unilateral Feet	0	3	3	0.010	1	1	2	0.105
Bilateral Hands	85	91	176	0.587	1	4	5	0.263
Bilateral Feet	0	0	0	0.000	0	0	0	0.000
Bilateral Hands, Bilateral Feet	2	2	4	0.013	0	0	0	0.000
Unspecified	1	0	1	0.003	0	0	0	0.000
Total	160	141	300		9	10	19	

Table 6. Unilateral Cases of *Pedunculated Postminimus* (No Associated Malformation)

	American Negro			American White		
Location of Polydactyly	Females	Males	Total	Females	Males	Total
Left Hand	64	38	102	5	4	9
Right Hand	7	4	11	0	0	0
Unspecified	0	2	2	0	0	0
Total Unilateral Hands	71	44	115	5	4	9
Left Foot	0	3	3	2	1	3
Right Foot	1	1	2	1	1	2
Unspecified	0	0	0	0	0	0
Total Unilateral Feet	1	4	5	3	2	5

ALBINISM

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Generalized oculocutaneous albinism, abbreviated here as albinism, is an inborn error of metabolism with a world-wide distribution. The overall incidence of albinism in European populations is about 1 in 20,000, with estimates varying from 1 in 10,000 in Norway to 1 in 29,000 in Italy (Pearson et al. 1911-1913). Higher incidence values have been recorded in other populations. A prevalence value greater than 1 in 3750 occurs among the Navajo Indians in southwestern United States (Woolf 1965). Among school children in the township of Lagos, in southwestern Nigeria, a prevalence of 1 in 2858 was reported by Barnicot (1952). Prevalence values of about 1 in 200 occur among the Cuna Indians of San Blas Province, Lower Panama (Keeler 1964), Jemez and Zuni Indians of New Mexico, and the Hopi Indians of Arizona (Woolf 1965; Woolf and Grant 1962; Woolf and Dukepoo 1969). One of the highest prevalence values occurs among the Brandywine triracial (Negro, Caucasian, Amerindian) isolate of Maryland. In this isolate of about 5000 individuals, the prevalence of albinism is about 1 in 85 (Witkop et al. 1966).

Witkop et al. (1970) have shown that both tyrosinase-positive (ty-pos) and tyrosinase-negative (ty-neg) types of albinism occur in man. Each type may show recessive autosomal inheritance. The offspring of marriages between ty-pos and ty-neg albinos are normal, indicating that different autosomal loci are involved (Trevor-Roper 1952; Witkop et al. 1970). Although there is some overlap, especially in younger individuals, phenotypic differences exist between the two types. Ty-neg albinos have white hair, pink skin, translucent gray blue irides and severe nystagmus and photophobia. Ty-pos albinos are characterized by gradual accumulation with age of pigment in the eyes, skin, and hair, and in general exhibit only

moderate nystagmus and photophobia. In North Carolina ty-pos albinism is about twice as frequent as ty-neg albinism among Negroes; these frequency values are approximately reversed among Caucasians (Witkop et al. 1970). Albinos occurring in the Cuna and Zuni Indians and members of the tri-racial Brandywine isolate in Maryland are ty-pos (Witkop et al. 1970). It is assumed that this is the type of albinism occurring in the Hopi, Jemez, Navajo and other southwestern Indians. The phenotype of these albinos, with their flaxen hair, supports this hypothesis.

The detrimental nature of albinism is well documented (Keeler, 1964) with metastatic skin cancer being a common disease among those who are not protected from the sun. Neel et al. (1949) conclude that in past generations the relative reproductive (Darwinian) fitness (W) of albinos was about 0.4 to 0.5. A relative fitness of 0.4 implies that albinos leave 40 functional offspring for every 100 left by nonalbinos. When a deleterious trait is due to an autosomal recessive gene (c), and when carriers (Cc) and noncarriers (CC) have the same relative fitness ($W=1$), the frequency of affected individuals (cc) in a large population is a function of both the mutation rate (μ) and the selection coefficient ($s = 1 - W$) against affected individuals. The frequency of affected individuals at equilibrium is $R = \mu/s$. The mutation rate at the ty-pos albino locus is unknown, but if a value of $1/50,000$ is assumed (that is, there is one gamete containing the mutant gene among 50,000 produced), and the relative fitness of these albinos is given the value of 0.4, the frequency of ty-pos albinos at equilibrium in a large population would be $R = \mu/s = (1/50,000)/(0.6) = 1/30,000$. Mutation pressure and selection against albinos probably accounts for the frequency of individuals with this inborn error of metabolism in most world populations. The occurrence of populations with a

high frequency of ty-pos albinos, such as 1 in 200, indicates that some force other than mutation pressure and natural selection has been operating in past generations.

Hrdlička (1908) visited the Hopis in 1900 and described eleven albinos from ten sibships. Based on an estimated population size of about 2000, the reported prevalence was 1 in 182. Hrdlička missed three albinos living on the reservation at that time (Woolf and Dukepoo 1969). His estimate of the population size may also have been in error. A pilot study (Woolf and Grant 1962) verified Hrdlička's observation that albinos are common in the Hopi population. The observed frequency in 1962 was about 1 in 227. The Hopi reservation is located in northwestern Arizona where it is completely surrounded by the Navajo reservation. Eleven of the twelve existing Hopi villages are located on the top or at the base of three mesas, known as First, Second, and Third Mesa. One village (Moenkopi) is located on the western range of the Navajo reservation but is actually an offshoot of the Third Mesa population. One of the three villages on First Mesa was established by Tewa emigrants from the Rio Grande area in New Mexico, in about 1700, following the Pueblo revolt against Spanish authority during the latter part of the seventeenth century (Dozier 1954). The Hopi and Tewa Indians on First Mesa have intermarried extensively so that First Mesa should be considered as a Hopi-Tewa gene pool. Further investigations (Woolf 1965; Woolf and Dukepoo 1969) of albinism on the Hopi reservation revealed that generalized oculocutaneous albinism is restricted to the Second and Third Mesa populations. In 1968, there were 26 living albinos. Based on an estimated population size of 5000 for Second and Third Mesa, this observed number of albinos gives a frequency value of about 1 in 192. First Mesa is devoid of any individual with generalized

oculocutaneous albinism. No living Hopi remembers any albino of this type being born at First Mesa; furthermore, there is no recorded evidence for such an event. However, a gene causing partial albinism and subtotal nerve deafness is present in the First Mesa population (Woolf 1965; Woolf, Dolowitz and Aldous 1965). The gene giving this syndrome may be located in the X chromosome or an autosome. Two brothers were born in 1952 and 1956 with the syndrome. No other case occurs in the Hopi population. However, Bourke (1884:343), in a narration of his journey to the Hopi reservation in 1881, described a young Hopi boy with the physical features of this syndrome, suggesting that the gene has been segregating in members of this population in past generations.

Stephenson (1904) documented the presence of albinos among the Zunis. This reference plus personal reports of the occurrence of albinos in other Indian populations in Arizona and New Mexico were the catalyst for a study by the present author to determine which Indian populations in these states have a high prevalence of albinos (Woolf 1965). The Indian populations surveyed and the results of the survey are given in Table 1. The majority of the Indian populations in Arizona and New Mexico have no living albinos; three stand out as high prevalence populations: Hopi Indians (1 in 227) in Arizona and the Zuni (1 in 247) and Jemez Indians (1 in 140) in New Mexico. Albinism occurs at lower prevalence values in the Laguna (1 in 2000) and San Juan Indians (1 in 500) in New Mexico, and the Navajo Indians (1 in 3750) in Arizona, New Mexico, Colorado, and Utah. Albinism in the Laguna and San Juan Indians can be attributed to gene flow among the New Mexico pueblo Indians. The presence of the albino gene in the Navajo population is explainable by the close proximity of the Navajo reservation to the Hopi and

Zuni reservations and by Navajo raids in the past on the Hopis and Zunis for the purpose of obtaining food, women, livestock and other booty. Several of the Navajo families with albinos reside near the Hopi reservation.

What is the explanation for the high frequency of ty-pos albinos in the Hopi, Jemez and Zuni Indians? Possible explanations are the founder principle, genetic drift, selection for the heterozygote, some type of cultural selection, or a combination of one or two of these forces. It is evident that the reason for a high frequency in one of these populations may not be the same reason for a high frequency in another population.

FOUNDER PRINCIPLE AND GENETIC DRIFT

A gene may be common in a population if one or more of the few early founders carried the gene. Witkop et al. (1966) conclude that the frequency of albinos in the Brandywine triracial isolate in Maryland is due to the founder principle. All albinos in this inbred population trace their ancestry to a single pair of individuals who were among the founders of the present population. Jones (1965) prepared pedigrees of the albinos in the Jemez population and suggested that the high frequency of albinism in this population can at least partly be attributed to migration. A number of the albinos or heterozygotes are of Pecos descent. While the Pecos Pueblo in New Mexico was at one time a flourishing community of over 2000 individuals, it was reduced to 17 individuals in 1838 by Commanche raids and diseases introduced by Europeans. These 17 individuals migrated to Jemez and helped found the present Jemez population. Jones proposes that these migrants either introduced the albino gene into the small Jemez gene pool or sub-

stantially increased the frequency of the albino gene in this pool. Whether the founder principle is the total explanation for the high frequency of albinism at Jemez or in any other southwestern Indian population has yet to be determined; however, it is a hypothesis that has merit.

Indian populations in the southwest have been plagued by epidemics, periodic starvation conditions and raids by hostile groups. As a consequence, these populations have often consisted of a small number of individuals and the number has remained small over many generations. If the albino gene were present in one of these small populations, the frequency of the gene would be expected to fluctuate from generation to generation by chance segregation and recombination. The recessive gene for albinism may well have reached a high frequency in one or more Indian populations by this force of genetic drift. Stern (1960:271) gives genetic drift as one possible explanation for the high frequency of albinism among the Cuna Indians in Panama.

If the chance process of genetic drift or the founder principle is the explanation for the high frequency of albinism in the Hopi, Jemez, or Zuni Indians, what is the origin of the mutant gene? The ty-pos albino gene in these three different Indian populations is likely "identical by descent" since gene flow has occurred among the Pueblo Indians of Arizona and New Mexico in historic and prehistoric times (see Woolf 1965). The presence of ty-pos albinism in the remote Cuna Indians of Lower Panama suggests further that the mutant gene is not of recent origin and draws attention to Central America as the possible site of origin. There were many albinos in Montezuma's royal household at the time of the conquest. Albinos along with malformed individuals were considered by the Aztecs

as wards of the state. In Prescott's account (p. 320) of Montezuma's royal household at the time of the conquest of Mexico, the following is found:

I must not omit to notice a strange collection of human monsters, dwarfs, and other unfortunate persons, in whose organization Nature had capriciously deviated from her regular laws. Such hideous anomalies were regarded by the Aztecs as a suitable appendage of state. It is even said, they were in some cases the results of artificial means, employed by unnatural parents desirous to secure a provision for their offspring by thus qualifying them for a place in the royal museum.

Numbered in quantity among the unfortunate persons under Montezuma's protection were albinos (Orazco y Berra 1880:381):

There was in this house a room in which there were men, women and children, white at birth in the face, body, hair, eyebrows and eyelashes.

The extent of the practice of protecting malformed children in Central America before the coming of Cortez is unknown. The protection of albinos by the early Aztecs could have served as the catalyst for the propagation of the albino gene at an increased frequency in certain segments of the population and its dissemination by migration to various regions in Central America and the southwestern part of the United States.

SELECTION FOR THE HETEROZYGOTE

A slight discontent is associated with the conclusion that ty-pos albinism reached a high frequency in four different Indian populations (Cuna, Hopi, Jemez, and Auni) by only the chance processes of the founder principle or genetic drift. For this reason other mechanisms should be considered that could act by themselves or in conjunction with a chance force. One such mechanism is selection for the heterozygote.

A deleterious recessive gene will be maintained in a population at an increased frequency if the heterozygotes has a reproductive advantage. For example, if the relative reproductive fitness values (W) of heterozygotes (Cc) and albinos (cc) were 1.00 and 0.5, respectively, the relative fitness of non-carriers (CC) would only have to be 0.962 in order to maintain an albino frequency of $R = 1/200$ in a large population. This slight advantage of the heterozygote, which would be difficult to measure in a practical situation might manifest itself by increased fertility, vigor, maturation rate, or resistance to a disease. An argument against the heterozygote advantage hypothesis for albinism is that environmental conditions are not too different at the present time among the various Indian Pueblo groups in Northern Arizona and New Mexico, even though large differences exist in the frequency of the albino gene in these groups. A heterozygote advantage in one population should be found in all other populations with similar environmental conditions. Yet, it is clear that relative fitness values can be influenced by genetic background (Woolf and Knowles 1964). In the presence of a specific homozygous background produced by genetic drift and many generations of inbreeding, heterozygosity for certain mutant genes might

increase reproductive fitness. A corollary would also be that the advantage ceases with the advent of genetic variability. The presence of albinism at a high frequency in some populations and not others would imply that the latter lacked the proper genetic background or the allele had not been introduced by migration or mutation. Reed (1965) has speculated that the advantage of the heterozygote may be due to genes adjacent to the albino locus rather than at the albino locus.

Some type of advantage of the heterozygote cannot be ruled out as the explanation for the high frequency of albinism in various Indian populations. This hypothesis has bearing on the suggestion of Jones (1965) that the albino gene was introduced into the Jemez population by the 17 Pecos Indians who survived Comanche raids and diseases introduced by Europeans. If this was the origin of the albino gene in the Jemez population, was it merely chance that the gene was present in some of these survivors, or did heterozygosity for the gene increase the probability of surviving a disease introduced by Europeans?

CULTURAL SELECTION

If an Indian population acquired a high frequency of the deleterious ty-pos albino gene by either genetic drift or the founder principle, natural selection should be instrumental in decreasing the frequency from generation to generation. Natural selection against the gene would be more effective in the hot desert populations of southern Arizona than in the more temperate climates of northern Arizona and New Mexico. Pueblo dwellings which afford protection from the sun would lessen the effectiveness of natural selection. An interesting question is whether the impact of natural selection could have been further lessened at any

given time in any pueblo population by cultural attitudes or practices with the consequence that the gene was maintained at a high frequency, or even increased in frequency in at least a segment of the population. This possibility was explored carefully for the Hopi Indians (Woolf and Dukepoo, 1969).

Traditional Hopis reflect only a positive attitude towards albinos and state there is complete acceptance of them in their society. Albinos perform in ceremonies along with other Hopis, and several have been influential chiefs and priests. They are considered as part of the Hopi heritage on Second and Third Mesa (Woolf and Dukepoo 1969). Marriage is important in the life of a Hopi. It is extremely rare to find an adult, especially a woman, who has never been married. The fact that many albinos have remained unmarried contradicts the attitude of complete acceptance in the traditional Hopi society. One albino male stated he was unable to work in the fields and therefore could not grow corn for a wife and family. Although the inability to provide for a family is the excuse usually given for males, the reason is not obvious for females. The acceptance by Hopis of this Hopi heritage apparently stops at marriage. Females should reject males who cannot work in the fields. However, any real or subconscious bias towards marrying an albino apparently does not manifest itself in the selection of a temporary sex partner. Hopis for centuries have made their living by farming. Men and boys would leave the mesa tops and go to the fields, often many miles from the mesas. It is commonly known among the inhabitants of Second and Third Mesa that albino males were not expected to labor in the fields. They remained in the villages and performed tasks such as weaving. In the villages they were protected from the sun and hostile nomads, and most importantly, albino males had ample time and

often the opportunity to engage in sexual activity. One albino male is especially legendary for this activity:

I knew that old man. Some say
he had about twelve kids; others say about
fifteen.

He never married.

They say he was always around trading
with the ladies. He would make babies with
them.

He was real funny, and knew a lot of
good stories. Everyone liked him.

If the high frequency of albinism in the Hopi population were initially due to genetic drift or the founder principle, it is certain that the acceptance and protection of albinos by the Hopis would reduce the effectiveness of natural selection in reducing the frequency of this deleterious gene. Furthermore, in a small population, a sexually active male will have an imposing effect on gene frequencies in subsequent generations. This effect has been described by Neel (1970:817-818) for the Yanomama Indians of southern Venezuela and northern Brazil, where the award for male achievement is extra wives. It was noted that a greatly disproportionate number of grandchildren were born to a few males. The sexual activity of some albino males during the daytime in the villages on top of the mesas may have given the gene frequency a thrust upward in segments of the population during certain periods of time. Whether a similar phenomenon could have influenced gene

frequencies in the Jemez and Zuni populations in past generations is unknown. The Jemez and Zuni Indians are similar to the Hopi Indians regarding the acceptance and protection of albinos (Woolf 1965:28-29). Jemez and Zuni albinos also tend not to marry. However, it is expected that cultural practices regarding albinos might differ among populations and at different times within a population. For example, the frequency of albinism is high among the Cuna Indians of Panama in spite of apparent cultural selection against albinos in some of the Cuna towns, including infanticide (Keeler, 1964). This suggests that the gene frequency in the Cuna population is decreasing each generation from a high value caused by genetic drift or the founder principle, or is being maintained by selection for the heterozygote.

CONCLUSION

The recessive gene for albinism is spread widely through Indian populations of Central America and the southwestern part of the United States. The gene is at a high frequency among the Cuna Indians of San Blas Province, Lower Panama, the Jemez and Zuni Indians of New Mexico, and the Hopi Indians of Arizona. The protection of albinos by the early Aztecs may have served as a catalyst for the propagation of the gene at an increased frequency in certain segments of the population and its eventual dissemination to various regions by migration.

Because of the detrimental nature of this inborn error of metabolism, the existence of Indian populations with a high prevalence of albinos presents an intriguing problem in population genetics. Although selection for the heterozygote could be the major reason for the high frequency of the gene in these populations, other hypotheses may be more tenable. A hypothesis to explain the high frequency

among the Hopi Indians of Arizona involves an interaction of the chance process of genetic drift or the founder principle with a form of cultural selection. The reason for a high frequency in one Indian population may not be the same reason for a high frequency in another population.

A study of the Hopi, Jemez and Zuni Indians in the southwestern part of the United States indicates that time will soon erase albinism as a heritage of these people. Modern transportation facilities, schools on and off the reservation where members of different ethnic groups associate, and growing populations forcing young people to seek employment off the reservation all promote outbreeding, reduce the frequency of the albino gene, and decrease the probability of homozygosity for this gene. The frequency of albinism in these populations will decrease rapidly with the decline of their cultures.

Table 1. Prevalence of Albinism in Southwest Indian Populations in 1967

Population	Estimated population size	Number of albinos	Estimated prevalence
Acoma, New Mexico	2,400	0	
Apache (Jicarilla), New Mexico	1,400	0	
Apache (Mescalero), New Mexico	1,500	0	
Apache, Arizona	11,000	0	
Cochiti, New Mexico	600	0	
Hopi, Arizona	5,000	22	1 in 227
Isleta, New Mexico	2,000	0	
Jemez, New Mexico	1,400	10	1 in 140
Laguna, New Mexico	4,000	2	1 in 2,000
Navajo, Arizona, New Mexico, Colorado, Utah	90,000	24	1 in 3,750
Papago, Arizona	9,000	0	
Picuris, New Mexico	150	0	
Pima, Arizona	7,000	0	
San Felipe, New Mexico	1,300	0	
San Ildefonso, New Mexico	290	0	
San Juan, New Mexico	1,000	2	1 in 500
Sandía, New Mexico	200	0	

Santa Ana, New Mexico	400	0	
Santa Clara, New Mexico	800	0	
Santo Domingo, New Mexico	1,900	0	
Taos, New Mexico	1,300	0	
Zia, New Mexico	425	0	
Zuñi, New Mexico	4,200	17	1 in 247

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A GENETIC STUDY OF SYNDACTYLY IN UTAH

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This work was supported by U. S. Atomic Energy Commission Contract
AT (11-1) -2013 to Arizona State University

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As part of a genetic study of certain types of congenital malformations in Utah, family histories were obtained for Caucasian probands classified as having polydactyly or syndactyly. These probands were obtained from hospital records made available by physicians. Each proband was a surgical case. The objective of the study was to gain information that would be of value in genetic counseling. This study was carried out in a population that is predominantly Mormon (Church of Jesus Christ of Latter-day Saints). The relative stability of the Mormon population in the area, strong family ties and an interest in genealogy, facilitate family history studies of this type among Mormon people in the state of Utah. The probands were sorted into two groups: (1) polydactyly cases without associated syndactyly, and (2) syndactyly cases with or without associated anomalies. The results of the polydactyly study have been published (Woolf and Woolf, 1970).

Plastic and orthopedic surgeons frequently encounter patients with syndactyly. The following questions may be asked: What types of syndactyly have a genetic basis? What modes of inheritance are present? What types of syndactyly are encountered in a sample of surgical cases? What proportion of patients with a given type of syndactyly have a family history of the same type? Meaningful genetic counseling must consider that syndactyly is characterized by phenotypic variability and genetic heterogeneity. On the basis of a review of the literature and their own experiences, Temtamy and McKusick (1969) have presented a useful classification of syndactyly types:

Type I Syndactyly: Zygodactyly. Webbing between the third and fourth fingers (complete or partial) with occasional involvement of other fingers. Webbing between the second and third toes (complete or partial). The hands and/or feet may be affected. In members of some families, only the feet are affected.

Type II Syndactyly: Synpolydactyly. Webbing between the third and fourth fingers associated with the presence of all components or part of an extra finger in the web. Webbing of the fourth and fifth toes associated with the presence of all components or part of an extra toe in the web. The hands and/or feet may be affected.

Type III Syndactyly: Fourth and Fifth Finger Syndactyly. Webbing between the fourth and fifth fingers. The fifth finger in the web may be short with rudimentary or absent middle phalanges. The feet are not affected.

Type IV Syndactyly: Haas Type. Complete webbing of the fingers with six metacarpals and six digits, associated with flexion of the fingers giving the hands a cup-shaped form.

Type V Syndactyly: Syndactyly with Metacarpal and Metatarsal Fusion. Webbing of the third and fourth fingers, second and third toes, associated with metacarpal and metatarsal fusion.

Although genetic heterogeneity is likely present, all of the above types of syndactyly have shown dominant autosomal inheritance in families reported in the literature. Pedigrees have also been presented (McClintock, 1935, Goodman, 1965) demonstrating that a dominant gene may give various

expressions of syndactyly in association with preaxial and/or postaxial polydactyly. This condition is classified by Tentamy and McKusick (1969) as a type of polydactyly and referred to as polysyndactyly. Syndactyly is also an integral part of many different syndromes such as anhidrotic ectodermal dysplasia, Laurence-Moon-Bardet-Biedl syndrome, Poland syndrome, oculodentodigital dysplasia, and acrocephalosyndactyly (such as Apert's syndrome). Syndactyly may also occur in association with certain types of brachydactyly and other dactyl malformations where there is an absence deformity, such as split hand/split foot (Tentamy and McKusick, 1969).

PROCEDURE AND RESULTS

Upon receiving the names of the probands from hospital surgical records, current addresses were obtained from telephone books, city directories or church records. Cases were omitted from the study if current addresses were not available or if family members were no longer residing in the state of Utah. The homes were visited by field workers who obtained information of epidemiologic interest. Information on the presence or absence of a congenital malformation was obtained for at least the following relatives of the proband: sibs, children, parents, grandparents, aunts, uncles and first cousins. When it was learned that more distant relatives had a dactyl anomaly, the pedigrees were extended to include them. When a positive family history was encountered, an attempt was made to obtain a reliable description of the anomal-

ies present in the affected family members. This was done by utilizing medical records (surgical, x-ray) when available, or by obtaining a description of the anomaly from close relatives. For deceased members of older generations, the descriptions were often cursory, and sometimes conflicting. Family histories were obtained for 64 probands. These probands were unselected as to type of syndactyly; the only criterion was that the name of each had appeared on a hospital surgical record with the diagnosis of syndactyly. Based upon x-ray and medical records as well as the family history, an attempt was made to classify each proband as to type of syndactyly. Forty-one had syndactyly with or without polydactyly. Twenty-three had syndactyly associated with other anomalies.

Syndactyly With or Without Associated Polydactyly:

The 41 probands with or without associated polydactyly were classified into four groups: (1) Type I syndactyly, (2) Type II syndactyly, (3) Type III syndactyly, and (4) syndactyly associated with polydactyly other than what is found in cases of synpolydactyly (Type II syndactyly). No proband was encountered that could be classified as having Type IV or Type V syndactyly.

Type I Syndactyly: Twenty-three (56.1%) of the 41 probands were classified as having Type I syndactyly. Thirteen (56.5%) of the 23 probands had a family history of this disorder. Autosomal dominant inheritance is indicated in these 13 kindreds. Representative pedigrees are presented in Figures 1 and 2. Genetic heterogeneity is undoubtedly

present for Type I syndactyly. In 2 of the 13 kindreds, the webbing in affected members is restricted to the second and third toes. Similar types of pedigrees appear in the literature (Gates, 1946), including the Schofield pedigree which at one time was used as an example of holandric inheritance (Stern, 1957). The number of affected individuals in some of these kindreds is small, and therefore only a limited sample exists of gene expressions. However, it is apparent that a dominant autosomal gene is segregating in some families that causes webbing between the second and third toes with no involvement of the hands. This type of syndactyly will be referred to here as Type Ia syndactyly. A different allele, or more likely, a mutation at a different autosomal locus, would therefore account for the type of syndactyly which involves the third and fourth fingers and/or second and third toes (referred to here as Type Ib syndactyly). Eleven of the 13 kindreds exhibited Type Ib syndactyly. Representative pedigrees are presented in Figure 2. In all affected members of these kindreds the webbing involves either the third and fourth fingers and/or the second and third toes with the exception of the propositus in Kindred 13. In this individual, webbing involved digits 2 and 3, 3 and 4, and 4 and 5 of each hand. The mother of this propositus, who was the sole affected relative, had bilateral webbing between the third and fourth fingers.

Type II Syndactyly: Ten (24.4%) of the 41 propoiti were classified as having Type II syndactyly. All are characterized by some expression of synpolydactyly involving webbing of the third and fourth fingers and/

or fourth and fifth toes. Five (50%) of the 10 propoiti had a family history of synpolydactyly. Autosomal dominant inheritance is present in these five kindreds. Representative pedigrees are shown in Figure 3. Three of the 5 propoiti with a positive family history have a common ancestor. Each was ascertained independently from a different source of records. The immediate family names are dissimilar. The common ancestor was discovered only after the pedigrees of each was expanded by the field workers to include other affected individuals. The kindred to which each belongs was described in the literature in 1947 by Alvord. The progenitor of this kindred, who had webbing between the third and fourth fingers of the right hand was a polygamist with 2 wives and 14 children.

Type III Syndactyly: Four (9.8%) of the 41 propoiti were classified as having Type III syndactyly based on the criterion of webbing between the fourth and fifth fingers. One of these propoiti also had slight webbing between fingers two and three and shortness of the index and little finger. X-rays were not available for this propoitus. Another propoitus had a rudimentary middle phalanx of the fifth digit. The other two propoiti had bilateral complete webbing of digits 4 and 5, but there was no apparent abnormality of any of the phalanges. Although Type III syndactyly shows a dominant mode of inheritance in some families (Johnston and Kirby, 1955), all 4 of the propoiti classified as having this type of syndactyly in this study were sporadic cases. A familial occurrence likely would have been encountered with a larger number of index cases.

Syndactyly Associated with Polydactyly (Other than Synpolydactyly):

Four (9.8%) of the 41 propoiti had expressions of syndactyly and polydactyly other than what is found in cases of synpolydactyly (Type II syndactyly). Two of these propoiti had a family history of the same condition. Pedigrees of these two families are shown in Figure 4 (Kindreds 18 and 19). The propoitus in Kindred 18 had partial webbing of the second and third toes of both feet and bilateral preaxial polydactyly of the feet. The X-ray report stated there was virtually complete reduplication of the first digit with the base half of each first metatarsal being bifid in nature. A similar condition was present in one sib; another sib and father lacked polydactyly but had complete bilateral webbing between the second and third toes.

The propoitus of the family represented in Kindred 19 was born with webbing between the fourth and fifth toes of the left foot associated with an extra fifth digit in this foot. Postaxial polydactyly type B (pedunculated postminimus) was also present in the right hand. Postaxial polydactyly was present in two sibs; one of these sibs had, in addition, a similar type of syndactyly of the right foot.

Syndactyly Associated with Other Anomalies

Family histories were also obtained for 23 propoiti with syndactyly associated with brachydactyly, macrodactyly, a deficiency syndrome, or other anomalies. Extreme variation existed among the propoiti for those malformations. Most of these propoiti were unilateral for the anomaly. The propoitus had acrocephalosyndactyly (Apert's syndrome).

Three others had the features of Poland syndrome including unilateral aplasia of the pectoralis major muscle. The family histories of all 23 propositi were negative for any dactyly malformation.

DISCUSSION

The types of syndactyly present in the 64 propositi used in this study do not represent the frequencies of types present at birth. There is a bias towards types that are treated surgically. Individuals with type Ia syndactyly rarely have surgical treatment of the webbing. No data have been published on the incidence of the various types of syndactyly in any population. It seems likely, however, that Type Ia syndactyly is the most frequent type. This is borne out by a study of the nursery records on file in the Latter-day Saints Hospital in Salt Lake City, Utah. These records have been used to obtain incidence values for various congenital malformations for the years 1951-1961 (Woolf and Turner, 1969). When a newly born infant is admitted to the nursery of this hospital specific information is logged in record book: surname, date of birth and sex. Any malformation or disorder noted by the attending physicians at the time of birth, or during the sojourn of the infant in the nursery, is made part of the record. The great majority of patients who enter this hospital are Caucasian. Hence, the nursery records reflect incidence values among live births for Caucasians living in or near Salt Lake City, Utah. The nursery records contain reliable information for obvious congenital malformations; however, by their nature,

they are not as complete as medical records. During the years 1951-1961, 59,561 live births occurred in this hospital, representing 23% of the total live births in the state for this period. Syndactyly with or without an associated malformation was noted in 18 of these infants giving an incidence of 0.30 per 1,000. This, of course, is a minimum value since cases were undoubtedly overlooked. Fourteen had syndactyly alone (0.24 per 1,000). The descriptions in the nursery records are cursory and cannot be used to estimate the incidence of the various different types of syndactyly. However, Type Ia syndactyly was present in at least 9 of the 18 cases indicating that it is the most frequent type of syndactyly.

The results of this study demonstrate that a sizeable proportion of the propositi from Utah with Type I and Type II syndactyly carry an autosomal dominant gene for those anomalies. Thirteen (56.5%) of the 23 propositi classified as having Type I syndactyly had a family history of this disorder compatible with dominant inheritance. Five (50%) of the 10 propositi with Type II syndactyly had a family history of syndactyly also compatible with this mode of inheritance. The sporadic cases may be mutant individuals where the egg or sperm giving rise to them contained a dominant mutant gene; it is also likely that some may be explained by recessive genes, polygenes, or unknown exogenous factors acting during development. The pedigrees shown in Figures 1-3 testify that the dominant genes giving rise to Type I and Type II syndactyly show reduced penetrance and variable expressivity. An individual with

the mutant gene may or may not show syndactyly. If it does manifest itself, webbing may involve toes and/or fingers and may be unilateral or bilateral. Typical expressions of Type I and Type II syndactyly are given in Figures 5, 6 and 7.

Pedigrees of polysyndactyly have been reported in the literature (McClintock, 1933; Goodman, 1965) with family members showing one or more of the following anomalies: postaxial polydactyly (Type B) of the hands, webbing between the third and fourth or fourth and fifth fingers, broad thumb, preaxial and/or postaxial polydactyly of the foot, webbing or 2 or more digits of the feet. In the affected members of these families polydactyly was present with or without associated syndactyly; syndactyly did not occur by itself. Further samplings of gene expression are needed, however, to determine if any deviation occurs in this mode of expression. Two of the four probands with associated polydactyly (other than the synpolydactyly cases) had the features of polysyndactyly. Expressions of this syndrome also appeared in the sibs of one of these probands. The parents of this sibship (see Kindred 19, Figure 4) and all other relatives are normal, however, a possible parentage problem exists. A suspected biological father of at least three of the children has bilateral webbing of the third and fourth fingers, as well as reported webbing of the third and fourth toes. He has a sister, a niece and a daughter with one or more features of polysyndactyly. The other two probands had preaxial polydactyly of the feet and webbing between the second and third toes. One case was unilateral and sporadic. Of special interest is the other case because of the family history of this

condition (see Kindred 18, Figure 4), where the propositus and sib had bilateral preaxial polydactyly of the feet with webbing between the second and third toes (see Figure 8); the father and another sib had bilateral complete webbing between the second and third toes. Preaxial polydactyly without accompanying syndactyly has an obscure etiology; it may have a polygenic mode of inheritance (Woolf and Woolf, 1970). It is problematical whether the dactyly anomalies present in the father and his three children constitute a new polydactyly-syndactyly syndrome or whether the condition is Type I syndactyly with the occurrence of preaxial polydactyly being fortuitous. This family needs to be followed in future generations; there should also be a lookout for families with a similar condition. In the study of polydactyly in Utah the families of four probands (2 with preaxial polydactyly and 2 with postaxial polydactyly) had a family history of syndactyly involving digits 2 and 3 of the feet. It was concluded that this type of syndactyly seems to be genetically independent of polydactyly in these families. Although this may be the case in most cases, certain genetic mechanisms may predispose to foot anomalies involving preaxial polydactyly and webbing between digits 2 and 3, as exemplified by the affected members of Kindred 18.

The results of the present study coupled with those from the study of polydactyly in Utah (Woolf and Woolf, 1970), give data that are useful for genetic counseling. Dominant inheritance is well documented for the majority of cases of Type I and II syndactyly. Although familial types of Type III syndactyly were not encountered in this study, the literature

testifies that this type of syndactyly may show dominant inheritance. The familial nature of polysyndactyly was also noted in one family, with suspected dominant inheritance. Of importance is the observation that syndactyly associated with other anomalies, such as brachydactyly, adactyly, multiple malformations, etc., in general, has a more complex etiology. The family histories for these types of propositi, are usually devoid of dactyly anomalies. The sporadic occurrence of Apert's syndrome and Poland syndactyly has been well documented. Exceptions are type B brachydactyly (symbrachydactyly) which has associated syndactyly, and some varieties of absence deformities (split hand/split foot), which frequently show dominant inheritance (Temtamy and McKusick, 1969). When polydactyly is present without associated syndactyly, the study of cases in the Utah population (Woolf and Woolf, 1970) demonstrated that dominant inheritance is often present for polydactyly involving an extra fifth digit or a triphalangeal digit in place of thumb, while duplication of the first digit very likely has a polygenic or some more involved mode of inheritance. For all types showing dominant inheritance, genetic counseling is complicated by the phenomenon of reduced penetrance. A normal child of an affected parent may not assume that he is free of the mutant gene.

SUMMARY

Family histories were obtained for 64 propositi with syndactyly. Forty-one had syndactyly with or without polydactyly. Twenty-three had

syndactyly associated with other anomalies. The names of the propositi were obtained from hospital records (surgical, x-ray, nursery) in the state of Utah.

A strong family history of the disorder was noted for those propositi with or without polydactyly. The family history was negative for the propositi with associated anomalies other than polydactyly. Thirteen of 23 propositi with Type I syndactyly (zygodactyly) had a family history of this disorder compatible with dominant inheritance. Five of 10 propositi with Type II syndactyly (sympolydactyly) had a family history of this condition also compatible with this mode of inheritance. Sporadic cases may be mutant individuals; it is also likely that some may be explained by recessive genes, polygenes, or unknown exogenous factors acting during development. Dominant inheritance was also noted for polysyndactyly (syndactyly with preaxial and/or postaxial polydactyly). The dominant genes giving rise to Type I syndactyly, Type II syndactyly, and polysyndactyly show reduced penetrance and variable expressivity.

ACKNOWLEDGMENTS

We wish to thank Mrs. Eloise W. Ellis and Mrs. Anna Beth Stucki for their excellent services as field workers in this study.

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SYNDACTYLY AND SEX RATIO

The genetic literature is replete with selected pedigrees of syndactyly. As demonstrated by this progress report, a study has been made of syndactyly in Utah. Propositi were selected from medical records in hospitals in the larger cities of Utah (Salt Lake City, Ogden, and Provo). Large kindreds were encountered with Type I Syndactyly (Zygodactyly) and Type II Syndactyly (Synpolydactyly). Of extreme interest is the sex ratio phenomenon for Type I Syndactyly, especially when the webbing only includes the second and third toes (referred to here as Type Ia syndactyly as contrasted with Type Ib syndactyly where webbing involves the third and fourth fingers and/or the second and third toes). A strong sex ratio favoring males occurs in the Utah kindreds with members showing Type Ia syndactyly. It is characteristic of pedigrees appearing in the literature. A brief review of the Utah pedigrees and those readily available in the literature does not yield an obvious reason for the sex difference. Two different hypotheses present themselves: (1) Incomplete penetrance in females, and (2) segregation distortion (sperm dysfunction?) involving the Y chromosome and autosome with the dominant mutant gene. An attempt is being made to obtain every published pedigree of Type Ia Syndactyly. This is being done by surveying the world literature. By using interlibrary loan and microfilm services, copies of these papers and pedigrees are being compiled. When a large sample of pedigrees is available, they will

be analyzed to test the two hypotheses. This study should be completed during the coming contract period.

SPINA BIFIDA CYSTICA IN UTAH

Controversy exists in the medical literature concerning the etiologic importance of genetics for spina bifida cystica (meningocele and myelomeningocele). Family histories have been obtained for 109 probands with spina bifida cystica. The frequencies of this disorder and other congenital malformations (including anencephaly and hydrocephaly) have been obtained in the following relatives of the probands: sibs, parents, grandparents, aunts, uncles, and first cousins. The frequency of spina bifida cystica in the sibs born subsequently to the probands is 1.77% ($n = 113$). It has been suggested in the literature that a genetic mechanism (polygenes?) giving spina bifida cystica may also express itself as anencephaly. The latter anomaly is not infrequent in stillborn infants; both anomalies may increase the probability that development will be arrested at an early stage. Hence, a genetic study of spina bifida cystica must consider stillbirths and spontaneous abortions.

The study is still in progress. The pregnancy histories of each mother of a proband are being brought up to date concerning miscarriages and subsequent fetal deaths and live births. In case of a fetal death, medical records and fetal death certificates are being reviewed for the

possible occurrence of a disorder of the central nervous system. The frequency of spontaneous abortions will be compared with a control group. This study will be finished during the next proposed contract period.

CONGENITAL HIP DISEASE AMONG THE APACHE INDIANS IN ARIZONA

Considerable variation exists among published incidence values for congenital hip disease. Representative values are as follows: Birmingham, England, 0.65/1000, Salford, England, 1.55/1000, New York City, 1.6/1000, Malmo, Sweden, 1.7/1000, Jerusalem, Israel, 9.8/1000 (Woolf, et. al., Am. J. Human Genetics 20: 430-439, 1968). High incidence populations are not uncommon. Rabin et. al. (Am. J. Public Health 55 (No. 2, Part II): 1-44) observed a prevalence rate of 38/1000 among infants and adults among Navajo Indians living at Many Farms, Arizona. An incidence of 60/1000 was reported for an Indian population living at Island Lake, Manitoba, Canada (Corrigan and Segal, Canad. Med. Ass. J. 62: 535-540, 1950). It has not been definitely determined whether genetic or nongenetic factors, or both, account for the increased incidence of hip disease in the Navajo and certain other Indian populations. Rabin et. al. (1965) concluded that the practice of binding infants on a cradle board, which has long been suspected as one cause of the increased incidence in this ethnic group, is not implicated directly in the etiology of the disease, at least in the population they

studied. Some of their cases showed improvement while on the cradle board; other dislocation cases were never on the board.

Preliminary studies have revealed that a high incidence of congenital hip disease also occurs among the Apache Indians in Arizona. Both the Navajo and Apache Indians are members of the Athabascan linguistic stock. There are two separate Apache Indian populations in Arizona, the White River (Fort Apache) population ($n = 6000$) and the San Carlos population ($n = 4700$). It has been demonstrated that the incidence of congenital hip disease is higher among the White River Apache Indians than among the San Carlos Apache Indians!

An investigation has been designed to determine the incidence of congenital hip disease in these two Apache Indian populations. Epidemiologic and inbreeding studies have also been planned. Studies of this kind need the approval of the U. S. Public Health officials and Tribal Council members. Although preliminary work on this investigation was initiated, it was only during August, 1972 that permission was obtained to conduct the work on the reservation (see proposal for 1973). Hence, little progress has been made on this project. It is proposed that a study of congenital hip disease among the Apache Indians will be the major research project of the next contemplated contract period, as measured by funds and time expended.

SEASON OF THE YEAR EFFECT FOR CONGENITAL HIP DISEASE

A strong genetic component exists for congenital hip disease (Woolf, et. al., Am. J. Human Genetics 20: 430-439, 1968). Genetic heterogeneity is likely present, with perhaps dominant and polygenic modes of inheritance being present (Woolf, Social Biology 18: 10-17, 1971). Nongenetic factors also play an important etiological role. A significant "season of birth effect" is present. Infants with the disease in Utah tend to be born during the autumn and early winter months. This effect has been noted for other populations. In all cases so far studied, the population is subjected to moderately cold winters. This effect needs further study. Records are being obtained through Crippled Children Services in various parts of the United States. Approximately 550 cases of congenital hip disease have been collected from Crippled Children Services in Los Angeles. Arrangements are also being made to obtain cases from the Northeastern part of the United States. Comparative studies may determine if the effect is correlated with cold weather, or whether some other "effect" is interacting.

It is also of extreme biological interest that congenital hip disease occurs at a high incidence among the Navajo and Apache Indians of Arizona, but not among the other large Indian tribes in the state such as the Hopi, Pima and Papago Indians. The Navajo and Apache Indians are biologically related, both being of the Athabascan linguistic stock. Records are being obtained for Navajo and Apache Indians with congenital hip disease from the Crippled Children's Hospital in Phoenix, Arizona and United States

Public Health Service Indian Hospitals at various locations in Arizona.

Tests will be run to determine if the factors causing congenital hip disease in these Indian groups interact with a season of the year effect.

CONGENITAL MALFORMATIONS AND ASYMMETRY OF DERMATOGLYPHIC PATTERNS

Because of the delay in receiving permission from the Indian Health Service to use all facilities in the study of congenital hip disease among the Apache Indians, the emphasis of the research program during January 1, 1972 - December 31, 1972, partially shifted to a study of symmetry of dermatoglyphic patterns in children with specific congenital malformations.

Dermatoglyphic patterns have been found to be very sensitive indicators of disturbed developmental processes. They develop during the early weeks and months of fetal life and are apparently completely formed by the sixteenth to eighteenth week. In a bilaterally symmetrical organism, many structures develop as mirror-images of one another. The organism attempts to do the same thing twice but almost always fails in this effort to a greater or lesser degree, particularly if the character in question is a continuously variable one. Dermatoglyphic patterns are an example of this phenomenon. The variance of a quantitative character in individuals of the same genotype is often taken as a measure of the developmental stability of the genotype. Likewise, the degree of symmetry may be used as a measure of developmental stability. If the symmetry is nondirectional

it is referred to as fluctuating asymmetry (Van Valen, Evolution 16: 125-142, 1962). Fluctuating asymmetry is thought to result from the inability of organisms to develop in precisely determined paths. Waddington (Genet. Res. 1: 140-150, 1960) refers to it as a consequence of developmental noise, i. e., random disturbances of patterns imparted to the organism by its genotype and the tangible environment. An increase in fluctuating asymmetry suggests a decrease in developmental buffering. Lack of buffering may be a consequence of homozygosity at specific loci (Lerner, Genetic Homeostasis, New York, Wiley, 1954).

Adams and Niswander (Genet. Res., 10: 313-317, 1967) have presented data showing that children with familial cleft lip (with or without cleft palate) have an increased asymmetry of molar teeth and the atd angle of palmar dermatoglyphics. Since the majority of cleft lip cases seem to have a polygenic mode of inheritance, these observations suggest that patients with cleft lip are less buffered because of homozygosity at specific loci (causing fluctuating asymmetry), or the genetic mechanism causing the facial cleft may also cause asymmetry of several different structures.

In order to obtain more data on asymmetry of dermatoglyphic patterns as an indicator of abnormal growth, children with specific malformations were selected from hospitals (Crippled Children's Hospital, St. Joseph's Hospital) in Phoenix, Arizona. Dermal prints were obtained for each of these children. The types of malformations and the number of children are as follows:

<u>Type of Malformation</u>	<u>Number</u>
Cleft lip with or without cleft palate	103
Club foot (Talipes equinovarus)	71
Congenital dislocated hip	69
Spina bifida cystica	62
Isolated cleft palate	<u>33</u>
Total	338

Controls consisted of 340 normal individuals. They were obtained from schools or head start programs, or were patients admitted to the hospitals for reasons other than illness or congenital defects, i. e., trauma, accidents, etc. An attempt was made to match the children with the malformations and controls for race, sex and age.

The following dermatoglyphic patterns were obtained for each individual:

1. Size of the atd angle.
2. Types of patterns on the finger tips (arches, tented arches, whorls, double loops, central pocket loops, ulnar loops or radial loops).
3. Presence or absence of patterns in the five palmar areas.
4. Ridge counts of the third finger of each hand.
5. Presence or absence of a simian line (or transitional forms of the simian line).
6. Pattern intensity index for fingers and palms.
7. C line present, absent or aborted.

Computer printouts are given in the following tables. The first table gives the analysis of the atd angle. The results are striking. Children with the congenital malformations are significantly more asymmetrical than controls. The intrapair variance is used as a measure of symmetry. For example, 50 Caucasian children with cleft lip had an intrapair variance of 74.38. The intrapair variance for 147 controls was 5.22. The F value is 14.2 ($P < 0.01$).

The remaining tables give the results of Mann-Whitney U tests used to analyze various palmar patterns for asymmetry. Letting $\alpha = 0.05$, and assuming a one-tailed test of significance, a z value greater than 1.64 leads to the rejection of the null hypothesis of no difference between the affected and control groups. The study is still in progress; many palmar patterns are yet to be analyzed. As shown in the tables, children with specific malformations tend to be more asymmetrical than controls for some patterns. Correlated studies are yet to be done.

KEY

Fingers

Are paired digits (right thumb-left thumb, right index finger-left index finger, etc.) similar for types of patterns on the finger tips? Individuals were scored from zero (no fingers alike) to five (all fingers alike). A score of zero for an individual indicates complete asymmetry; a score of 5 indicates complete symmetry.

Palms

Are patterns (radial loop, ulnar loop, carpal loop, whorl, etc.) alike in the five palmar areas of the right and left hands? Individuals were scored from zero (no areas alike) to five (all five areas alike). A score of zero indicates complete asymmetry; a score of 5 indicates complete symmetry.

Pattern intensity index, fingers

Are fingers alike for the number of triradii? The number on one hand may be ten; the number on the other hand may be ten. There may be five on one hand and four on the other. There may be none on each hand. The difference is a measure of asymmetry. A score of zero indicates complete symmetry; a score of 10 indicates the most extreme type of asymmetry.

Pattern intensity index, palms

Are the palmar areas alike for the number of triradii? As for the fingers, a score of zero indicates complete symmetry; a score of 10 indicates the most extreme type of asymmetry.

Main line index, D line

Does the D line exit in a similar region in both hands? The exit regions are numbered from 1 through 8. Symmetry is present if the exit region is the same in both hands (i. e., region 4 in the left hand, region 4 in the right hand, or region 6 in the left hand, region 6 in the right hand). Asymmetry is present if the exit region is not the same in both hands (i. e. region 4 in left and region 6 in the right hand.) The most extreme type of asymmetry for this trait would be region 1 in one hand and region 8 in the other hand. The difference is a measure of symmetry. A score of zero indicates complete symmetry. A score of 7 indicates the most extreme type of asymmetry.

Main line index A line

Does the A line exit in a similar region of both hands? A score of zero indicates complete symmetry; A score of 5 indicates the most extreme type of asymmetry.

Analysis of the atd angle of palmar dermatoglyphics — Measure- ment in degrees

	LEFT HAND				RIGHT HAND				LEFT FOOT			
	SUM	SS	MEAN	VAR	SUM	SS	MEAN	VAR	SUM	SS	MEAN	VAR
LEFT LIP CAUCASIAN	2405	120161	40.20	97.43	2484	123334	40.40	110.74	39	3675	18.78	14.38
LEFT LIP MEXICAN	1564	70140	40.45	74.05	1529	62981	40.41	94.49	31	2041	11.80	47.49
LEFT LIP INDIAN	891	40503	47.00	15.06	868	42160	48.00	46.44	13	429	1.71	34.71
LEFT FOOT CAUCASIAN	1470	61242	47.14	47.01	1957	91341	49.51	49.87	49	1561	1.60	35.33
LEFT FOOT MEXICAN	748	31290	54.07	80.00	987	53809	53.72	94.09	19	1299	11.01	75.24
LEFT FOOT INDIAN	270	17002	48.00	33.20	280	14734	48.33	142.47	14	496	12.33	92.07
RIGHT LIP CAUCASIAN	130	34240	48.14	46.05	166	17242	47.79	50.73	26	186	11.62	42.42
RIGHT LIP MEXICAN	360	17026	47.71	87.37	369	19144	51.71	78.00	14	716	12.70	114.07
RIGHT LIP INDIAN	1800	80600	44.10	21.70	1703	76933	42.00	79.16	45	1701	1.10	37.79
RIGHT FOOT CAUCASIAN	1244	63840	48.49	80.30	1250	63574	48.01	114.78	10	1494	0.30	139.41
RIGHT FOOT MEXICAN	844	46119	51.14	106.11	812	43412	49.53	140.76	27	2403	1.50	152.41
RIGHT FOOT INDIAN	463	24743	51.44	115.01	476	26604	52.49	170.41	13	435	1.44	97.53
LEFT PALM	1059	44909	48.04	37.25	1059	50331	48.04	50.80	0	924	0.00	42.09
RIGHT PALM	400	20072	48.00	114.07	464	22116	48.40	65.38	10	1402	1.40	70.40
CONTOURS CAUCASIAN	834	420490	43.04	59.04	643	270473	43.70	60.12	31	707	1.10	3.24
CONTOURS MEXICAN	3945	156417	45.07	86.41	3914	151442	45.51	38.94	31	1293	0.30	14.40
CONTOURS INDIAN	3491	146099	44.70	48.71	1764	115740	44.11	27.11	3	421	0.00	5.70
CONTOURS MEXICAN	1470	71432	47.40	45.49	1451	68907	40.07	26.72	25	921	0.01	30.03

MEXICAN
CLEFT LIP

VRS.

MEXICAN
CONTROLS

FINGERS

TEST MEASUREMENTS		RANK	
N = 30		R ₁ = 1504.5	
1		1	
N = 36		R ₂ = 5181.5	
2		2	
N = 1740.500		OR 439.500	
Z = 2.840			
CORRECTED Z = 2.960			

CAUCASIAN
CLEFT LIP

VRS.

CAUCASIAN
CONTROLS

FINGERS

*****		*****		*****		*****	
TEST				CONTROL			
MEASUREMENTS		RANK		MEASUREMENTS		RANK	
*****		*****		*****		*****	
N = 50		R = 3740.5		N = 147		R = 15762.5	
1		1		2		2	
*****		*****		*****		*****	
		U = 4884.500		OR 2465.500			
		Z = 3.473					
		CORRECTED Z = 3.652					
*****		*****		*****		*****	

CAUCASIAN
CLEFT LIP

VERS.

CAUCASIAN
CONTROLS

PALMS

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CAUCASIAN
CLEFT LIP

VRS.

CAUCASIAN
CONTROLS

PATTERN INTENSITY INDEX, FINGERS

*****				*****			
TEST				CONTROL			
MEASUREMENTS		RANK		MEASUREMENTS		RANK	
*****				*****			
N = 50		R = 5465.5		N = 147		R = 14137.5	
1		1		2		2	
*****				*****			
		U = 4190.500		JR		5159.500	
		Z = 1.480					
		CORRECTED Z = 1.627					
*****				*****			

CAUCASIAN
CLEFT LIP

VRS.

CAUCASIAN
CONTROLS

PATTERN INTENSITY INDEX, PALMS

*****											
*		*		*		*		*		*	
*	TEST	*		*		*	CONTROL	*		*	
*	MEASUREMENTS	*	RANK	*		*	MEASUREMENTS	*	RANK	*	
*		*		*		*		*		*	
*****											
*		*		*		*		*		*	
*	N =	50	R =	5263.5	*	*	n =	147	R =	14239.5	*
*	1		1		*	*	2		2		*
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CAUCASIAN
CLEFT LIP

VRS.

CAUCASIAN
CONTROLS

MAIN LINE INDEX, D LINE

TEST
MEASUREMENTS

RANK

CONTROL
MEASUREMENTS

RANK

N = 50
1

R = 5455.0
1

n = 147
2

R = 14348.0
2

U = 4180.000

or 3170.000

Z = 1.450

CORRECTED Z = 1.879

CAUCASIAN
CLEFT LIP

VRS.

CAUCASIAN
CONTROLS

MAIN LINE INDEX, A LINE

*****		*****		*****		*****	
* TEST *		* CONTROL *		* *		* *	
* MEASUREMENTS *		* MEASUREMENTS *		* RANK *		* RANK *	
*****		*****		*****		*****	
* N = 50 *		* N = 147 *		* R = 5793.0 *		* R = 13710.0 *	
* 1 *		* 2 *		* 1 *		* 2 *	
*****		*****		*****		*****	
* U = 4518.000 *		* OR = 2032.000 *		* *		* *	
* *		* *		* *		* *	
* *		* *		* *		* *	
* *		* *		* *		* *	
* CORRECTED Z = 3.243 *		* *		* *		* *	
*****		*****		*****		*****	

MEXICAN
CLEFT LIP

VRS.

MEXICAN
CONTROLS

PALMS

*****				*****			
TEST		RANK		CONTROL		RANK	
MEASUREMENTS				MEASUREMENTS			
*****				*****			
N = 30		R = 1602.5		N = 36		R = 5163.5	
1		1		2		2	
*****				*****			
U = 1442.500				OR 1137.500			
Z = 0.962							
CORRECTED Z = 1.016							
*****				*****			

MEXICAN
CLEFT LIP

VRG.

MEXICAN
CONTROLS

PATTERN INTENSITY INDEX, FINGERS

TEST		CONTROL	
MEASUREMENTS	RANK	MEASUREMENTS	RANK
N = 30	R = 1818.0	N = 86	R = 4968.0
1	1	2	2
U = 1353.000 OR 1227.000			
Z = 0.397			
CORRECTED Z = 0.439			

MEXICAN
CLEFT LIP
VRS.
MEXICAN
CONTROLS

PATENT INTENSITY INDEX, PALMS

TEST
MEASUREMENTS
RANK

CONTROL
MEASUREMENTS
RANK

$N = 30$
 $n = 1920.5$
 1

$n = 83$
 $R = 4265.5$
 2

$U = 1455.500$
 UN
 1124.500

$Z = 1.045$

CORRECTED $Z = 1.530$

MEXICAN
CLEFT LIP

VRS.

MEXICAN
CONTROLS

MAIN LINE INDEX, D LINE

*****				*****			
TEST				CONTROL			
MEASUREMENTS	RANK			MEASUREMENTS	RANK		
*****				*****			
N = 30	R = 1978.0			N = 80	R = 4008.0		
1	1			2	2		
*****				*****			

MEXICAN
CLEFT LIP

VRS.

MEXICAN
CONTROLS

MAIN LINE INDEX, A LINE

*****		*****		*****		*****	
* TEST *		* CONTROL *					
* MEASUREMENTS *		* RANK *		* MEASUREMENTS *		* RANK *	
*****		*****		*****		*****	
* N = 30		* R = 2211.0		* N = 86		* R = 4575.0	
* 1		* 1		* 2		* 2	
*****		*****		*****		*****	
		U = 1746.000		04		834.000	
		Z = 2.875					
		CORRECTED Z = 5.565					
*****		*****		*****		*****	

INDIAN
CLEFT LIP

VRS.

INDIAN
CONTROLS

FINGERS

TEST				CONTROL			
MEASUREMENTS				MEASUREMENTS			
RANK				RANK			
*****				*****			
N =	18	R =	606.0	N =	14	R =	5672.0
1		1		2		2	
*****				*****			
U = 877.000 OR 433.000							
Z = 2.274							
CORRECTED Z = 2.365							
*****				*****			

INDIAN
CLEFT LIP

VRS.

INDIAN
CONTROLS

PALMS

*****				*****				*****			
TEST		RANK		CONTROL		RANK					
MEASUREMENTS				MEASUREMENTS							
*****				*****				*****			
N = 18		R = 802.0		V = 74		R = 3476.0					
1		1		2		2					
*****				*****				*****			
				U = 701.000				OR 631.000			
				Z = 0.344							
				CORRECTED Z = 0.367							
*****				*****				*****			

INDIAN
CLEFT LIP

VRS.

INDIAN
CONTROLS

PATTERN INTENSITY INDEX, FINGERS

*****

TEST	RANK	CONTROL	RANK
MEASUREMENTS		MEASUREMENTS	

*****

N = 18	R = 890.5	N = 74	R = 3387.5
1	1	2	2

*****

U = 719.500	92	612.500
Z = 0.527		
CORRECTED Z = 0.575		

*****

INDIAN
LEFT LIP

VRS.

INDIAN
CONTROLS

PATTERN INTENSITY INDEX, PALMS

*****				*****			
TEST				CONTROL			
MEASUREMENTS		RANK		MEASUREMENTS		RANK	
*****				*****			
N = 18		R = 905.0		n = 74		R = 3372.0	
1		1		2		2	
*****				*****			

INDIAN
CLEFT LIP

VRS.

INDIAN
CONTROLS

MAIN LINE INDEX, D LINE

TEST				CONTROL			
MEASUREMENTS				MEASUREMENTS			
RANK				RANK			
N = 18				N = 74			
R ₁ = 740.9				R ₂ = 3536.4			
				</			

INDIAN
CLEFT LIP

VRS.

INDIAN
CONTROLS

MAIN LINE INDIAN A LINE

TEST		CONTROL	
MEASUREMENTS	RANK	MEASUREMENTS	RANK
N = 18	R = 1026.0	N = 74	R = 3252.0
1	1	2	2
U = 359.000 OR 477.000		Z = 1.860	
CORRECTED Z = 2.197			

CAUCASTAN
CLUB FOOT

VRS.

CAUCASTAN
CONTROLS

FINGERS

*****				*****			
TEST				CONTROL			
MEASUREMENTS	RANK			MEASUREMENTS	RANK		
*****				*****			
N = 43	R = 3146.0			N = 147	R = 14999.0		
1	1			2	2		
*****				*****			
U = 4121.000				OR 2200.000			
Z = 3.028							
CORRECTED Z = 3.162							
*****				*****			

CAUCASIAN
CLUB FOOT

VRS.

CAUCASIAN
CONTROLS

PALMS

*****		*****		*****		*****	
TEST				CONTROL			
MEASUREMENTS	RANK			MEASUREMENTS	RANK		
*****		*****		*****		*****	
N = 43	R = 3721.5			N = 147	R = 14423.5		
1	1			2	2		
*****		*****		*****		*****	

CAUCASIAN
CLUB FOOT

VRS.

CAUCASIAN
CONTROLS

PATTERN INTENSITY INDEX, PALMS

*****		*****		*****		*****	
*	*	*	*	*	*	*	*
TEST		CONTROL					
MEASUREMENTS		MEASUREMENTS		RANK		RANK	
*****		*****		*****		*****	
N = 43		N = 147		R = 4710.5		R = 15434.5	
1		2		1		2	
*****		*****		*****		*****	
N = 3764.500		OR		2556.500			
Z = 1.904							
CORRECTED Z = 2.300							
*****		*****		*****		*****	

CAUCASIAN
CLUB FOOT

VRS.

CAUCASIAN
CONTROLS

PATTERN INTENSITY INDEX, FINGERS

*****				*****			
TEST		RANK		CONTROL		RANK	
MEASUREMENTS				MEASUREMENTS			
*****				*****			
N = 43		R = 4150.5		N = 147		R = 13994.5	
1		1		2		2	
*****				*****			
U = 3204.505				OR 3116.505			
Z = 0.139							
CORRECTED Z = 0.153							
*****				*****			

CAUCASIAN
CLUB FOOT

VNS.

CAUCASIAN
CONTROLS

MAIN LINE INDEX D LINE

*****				*****				*****				*****			
TEST		RANK		CONTROL		MEASUREMENTS		RANK							
MEASUREMENTS				MEASUREMENTS											
*****				*****				*****				*****			
N = 43		R = 4930.0		N = 147		R = 13215.0									
1		1		2		2									
*****				*****				*****				*****			
				D = 3984.000				OR 2337.000							
				L = 2.596											
				CORRECTED Z = 3.240											
*****				*****				*****				*****			

CAUCASIAN
CLUB FOOT

VRS.

CAUCASIAN
CONTROLS

MATE LINE INDEX: A LINE

*****				*****			
TEST		CONTROL					
MEASUREMENTS		RANK		MEASUREMENTS		RANK	
*****				*****			
*****				*****			
N = 43		n = 5159.5		N = 147		n = 12935.5	
1		1		2		2	
*****				*****			
*****				*****			
U = 4213.500				OR 2107.500			
J = 3,320							
CORRECTED J = 4.334							
*****				*****			

MEXICAN
CLUB FOOT

VRS.

MEXICAN
CONTROLS

FINGERS

*****				*****			
TEST		RANK		CONTROL		RANK	
MEASUREMENTS				MEASUREMENTS			
*****				*****			
N = 16		R = 709.5		N = 86		P = 4750.5	
1		1		2		2	
*****				*****			
U = 1009.500				OR 538.500			
Z = 2.025							
CORRECTED Z = 2.122							
*****				*****			

MEXICAN
CLUB FOOT

VRS. MEXICAN
CONTROLS

PALMS

TEST
MEASUREMENTS

RANK

CONTROL
MEASUREMENTS

RANK

$N_1 = 18$ $T_1 = 875.1$

$N_2 = 36$ $T_2 = 1935.0$

$U = 844.000$ OR 704.000

$Z = 0.600$

CORRECTED $Z = 0.632$

MEXICAN
CLUB FOOT

VRS.

MEXICAN
CONTROLS

PATTERN INTENSITY INDEX, FINGERS

*****				*****			
TEST		RANK		CONTROL		RANK	
MEASUREMENTS				MEASUREMENTS			
*****				*****			
N = 18		R = 153.0		N = 80		R = 4707.1	
1		1		2		2	
*****				*****			

MEXICAN
CLUB FOOT

VRS. MEXICAN
CONTROLS

PATTERN INTENSITY INDEX, PALMS

TEST		CONTROL	
MEASUREMENTS	RANK	MEASUREMENTS	RANK
N = 18		N = 66	
1	1	2	2
R = 1261.0		R = 4199.0	
1 = 1090.006		OR 458.910	
2 = 2.715			
CORRECTED 2 = 3.361			

MEXICAN
CLUB FOOT

VRS.

MEXICAN
CONTROLS

MAIN LINE INDEX, A LINE

*****				*****			
TEST		RANK		CONTROL		RANK	
MEASUREMENTS				MEASUREMENTS			
*****				*****			
N = 18				N = 80			
1				2			
R = 1233.5				R = 4176.5			
1				2			
*****				*****			
U = 1112.500				U = 435.500			
S = 2.909							
CORRECTED T = 3.664							
*****				*****			

NEGRO
CLUB FOOT

VRS.

NEGRO
CONTROLS

FINGERS

TEST				CONTROL			
MEASUREMENTS				MEASUREMENTS			
RANK				RANK			
N = 6				N = 31			
R = 87.5				R = 615.5			
1				2			
U = 119.500				OR 66.500			
Z = 1.092							
CORRECTED Z = 1.155							

NEGRO
CLUB FOOT

VRS.

NEGRO
CONTROLS

PALMS

TEST MEASUREMENTS				CONTROL MEASUREMENTS			
RANK				RANK			
N = 6				N = 31			
R = 83.0				R = 620.0			
U = 124.000				OR 62.000			
Z = 1.277							
CORRECTED Z = 1.381							

NEGRO
CLUB FOOT

NEGRO
CONTROLS
VRS.

PATTERN INTENSITY INDEX, FINGERS

*****		*****		*****	
* TEST *		* CONTROL *		* RANK *	
* MEASUREMENTS *		* MEASUREMENTS *		* RANK *	
*****		*****		*****	
* N = 6 R = 125.0 *		* N = 31 R = 578.0 *		* N = 31 R = 578.0 *	
* 1 1 *		* 2 2 *		* 2 2 *	
*****		*****		*****	
* U = 204.000 OR 82.500 *		* U = 204.000 OR 82.500 *		* U = 204.000 OR 82.500 *	
* Z = 0.455 *		* Z = 0.455 *		* Z = 0.455 *	
* CORRECTED Z = 0.491 *		* CORRECTED Z = 0.491 *		* CORRECTED Z = 0.491 *	
*****		*****		*****	

4, 2, 1, 0

41 5.

COPIES

PATTERN INTENSITY INDEX, PALMS

RAFK

70. 17011

7. Asynchronous I/O

• HANA

$$\frac{N}{1} = \frac{6}{1} = 170.5$$
$$\frac{1}{2} = \frac{31}{62} \quad p = .5315$$
$$1. = \frac{150.500}{0,36.500}$$
$$= \frac{1}{2.56 \times 10^3}$$

~~"CORRECTED" 7 = 2.865~~

495.

THEODORE
COWLEY

MAIN LINE INDEX, P LINE

```

*****
*                                     *
*                                     *
*          TEST                      *
* MEASUREMENTS                      *          RANK
*                                     *
*                                     *
*****
*                                     *
*                                     *
* N =      6          R = 121.6
* 1          1
*
*****

```

[illegible]

$L' = 100,000$

17

86.000

$$L = \frac{0.28}{\lambda}$$

~~CORRECTED~~ 2 = 0.358

NEGRO
CLUB FOOT

VRS.

NEGRO
CONTROLS

MAIN LINE INDEX, A LINE

TEST
MEASUREMENTS RANK

N = 6 R = 125.0
1 1

CONTROL
MEASUREMENTS RANK

N = 31 R = 578.0
2 2

T = 104.000 OR 82.000

Z = 0.453

CORRECTED Z = 0.532

CAUCASIAN
CONG HIP

VRS.

CAUCASIAN
CONTROLS

FINGERS

TEST				CONTROL			
MEASUREMENTS		RANK		MEASUREMENTS		RANK	
*****				*****			
N = 16		R = 816.0		N = 147		R = 12550.0	
1		1		2		2	
*****				*****			

CAUCASIAN
CONTROLS

VSS.

CAUCASIAN
CONTROLS

PALIS

*****				*****			
TEST		RANK		CONTROL		RANK	
MEASUREMENTS				MEASUREMENTS			
*****				*****			
N = 16				N = 147			
1				2			
R = 1077.5				R = 12708.5			
*****				*****			
n = 1410.500				n = 941.500			
z = 1.308							
CORRECTED z = 1.404							
*****				*****			

CAUCASIAN
CONG HIP

VRS.

CAUCASIAN
CONTROLS

PATTERN INTENSITY INDEX, FINGERS

*****
* TEST *
* MEASUREMENTS * RANK *
*****

* N = 16 R = 1761.5
* 1 1

*****
* CONTROL *
* MEASUREMENTS * RANK *
*****

* N = 147 R = 11404.5
* 2 2

* = 1625.500 OR 726.500

* Z = 2.507

* CORRECTED Z = 2.740

*****

CAU ASIAN
CON HIP

VEG.

CAUCASIAN
CONTROLS

PATTERN INTENSITY INDEX, PALMS

TEST
MEASUREMENTS

RANK

N = 16
1

R = 1586.5
1

CONTROL
MEASUREMENTS

RANK

N = 147
2

R = 11779.5
2

U = 1450.500

OR

901.500

Z = 1.531

CORRECTED Z = 1.085

CAUCASIAN
CONTROL

VRS.

CAUCASIAN
CONTROLS

MAIN LINE INDEX, B LINE

TEST
MEASUREMENTS

RANK

CONTROL
MEASUREMENTS

RANK

N = 16
1

R = 1614.0
1

N = 147
2

R = 11552.0
2

U = 1678.000 OR 674.000

U = 2.800

CORRECTED Z = 3.571

CAUCASIAN
COGS HIP

VRS.

CAUCASIAN
CONTROLS

MAIN LINE INDEX, A LINE

*****		*****		*****	
TEST		CONTROL			
MEASUREMENTS	RANK	MEASUREMENTS	RANK		
*****		*****		*****	
N = 16	R = 1751.5	N = 147	R = 11614.5		
1	1	2	2		
*****		*****		*****	
U = 1612.500		OR 736.50%			
Z = 2.451					
CORRECTED Z = 3.387					
*****		*****		*****	

MEXICAN
CONS PIP

VRS.

MEXICAN
CONTROLS

FINGERS

*****				*****			
TEST				CONTROL			
MEASUREMENTS		RANK		MEASUREMENTS		RANK	
*****				*****			
N	=	7	R	N	=	36	R
1			1	2			2
*****				*****			
*****				*****			
U = 402.500				OR 199.500			
Z = 1.475							
CORRECTED Z = 1.552							
*****				*****			

MEXICAN
CONG HIP

VRS.

MEXICAN
CONTROLS

PALMS

*****				*****			
TEST		RANK		CONTROL		RANK	
MEASUREMENTS				MEASUREMENTS			
*****				*****			
*****				*****			
N = 7		R = 377.5		N = 30		R = 3993.5	
1		1		2		2	
*****				*****			
*****				*****			
U = 349.500				OR 252.500			
L = 0.705							
CORRECTED Z = 0.754							
*****				*****			

MEXICAN

CONG HIP

VRS.

CONTROLS

PATTERN: INTENSITY INDEX. FINGERS

TEST

MEASUREMENTS

RANK

CONTROL

MEASUREMENTS

RANK

N = 7

1

306.5

2

86

2

4004.5

U = 325.208

04

278.560

T = 0.529

CORRECTED Z = 0.562

*****	
TEST	
MEASUREMENTS	
RANK	
*****	
N =	7
H =	299.5
1	
*****	
CONTROL	
MEASUREMENTS	
RANK	
*****	
H =	2
H =	4671.5
2	
*****	
U =	330.503
OR	271.500
Z =	0.430
CORRECTED Z =	0.590
*****	

MEXICAN
 CONG RLP
 VRS.
 CONTROLS
 PATTERNS INTENSITY INDEX, FALLS

MEXICAN
CONG HIP

VRS.

MEXICAN
CONTROLS

MAIN LINE INDEX, D LINE

*****		*****	
* TEST *		* CONTROL *	
* MEASUREMENTS *		* MEASUREMENTS *	
* RANK *		* RANK *	
*****		*****	
* N = 7 P = 398.0		* I = 86 R = 3275.0	
* 1 1		* 2 2	
*****		*****	
* S = 368.000 OF 234.000		*****	
* R = 0.975		*****	
* CORRECTED Z = 1.131		*****	
*****		*****	

MEXICAN
CORG HIP

VRS.

MEXICAN
CONTROLS

MAIN LINE (HOLZ) A LINE

TEST
MEASUREMENTS

RANK

N = 7 R = 461.0
1 1

CONTROL
MEASUREMENTS

RANK

N = 56 R = 3910.0
2 2

$\bar{r} = 433.005$ OR 169.350

$\bar{c} = 1.922$

CORRECTED $\bar{c} = 2.552$

TFS

MEASUREMENTS

NY 4

41 = N

16

T

↓

12

1913.

1

2

13

42

42

2.

25

1. $\angle C = 90^\circ$

Should

CONG HIP

NY 1041

45

SECRET

NY 1041

7031100

SI 1947-054

31. 4. 21

CONFIDENTIAL

1291

17

1954

000'2822 = 11

000'2

000,257.

20

INDIAN
CONG HIP

VNS.

INDIAN
CONTROLS

PALMS

*****		*****	
TEST		CONTROL	
MEASUREMENTS	RANK	MEASUREMENTS	RANK
*****		*****	
N = 41	R = 2193.0	N = 74	R = 1477.0
1	1	2	2
*****		*****	
1 = 1792.000		OR 1552.000	
2 = 1.080			
CORRECTED Z = 1.144			
*****		*****	

INDIAN
CONG HIP

VRS.

INDIAN
CONTROLS

PATTERN INTENSITY INDEX, FINGERS

TEST		CONTROL	
MEASUREMENTS		MEASUREMENTS	
RANK		RANK	
N = 41		N = 74	
R ₁ = 2562.5		R ₂ = 4107.5	
U = 1701.500		OR 1332.500	
Z = 1.077			
CORRECTED Z = 1.157			

INDIAN
CONG HIP

VAS.

INDIAN
CONTROLS

PATTERN INTENSITY INDEX, PALMS

TEST		CONTROL	
MEASUREMENTS	RANK	MEASUREMENTS	RANK
N = 41	R = 2799.5	N = 74	R = 6570.5
1	1	2	2
U = 1938.500 OR 1095.500			
Z = 2.461			
CORRECTED Z = 2.966			

INDIAN
CONC HIP

VAS.

INDIAN
CONTROLS

MAIN LINE INDEX, D LINE

*****				*****			
TEST		RANK		CONTROL		RANK	
MEASUREMENTS				MEASUREMENTS			
*****				*****			
N = 41		R = 2530.		N = 74		R = 4140.0	
1		1		2		2	
*****				*****			
				U = 1669.000		OR 1365.000	
				Z = 0.884			
				CORRECTED Z = 0.957			
*****				*****			

INDIAN
CONG HIP

YES.

INDIAN
CONTROLS

MAIN LINE INDEX, A LINE

TEST
MEASUREMENTS

RANK

N = 41
1

R = 2933.5
1

CONTROL
MEASUREMENTS

RANK

N = 74
2

R = 3736.5
2

$t = 2072.500$ OR 951.581

$= 3.244$

CORRECTED $t = 3.669$

CAUCASIAN
SPINA BIFIDA

VER.

CAUCASIAN
CONTROLS

FINGERS

TEST MEASUREMENTS			CONTROL MEASUREMENTS		
		RANK			RANK
N = 26		R = 1929.5	n = 147		R = 15121.5
1		1	2		2
J = 2243.500 OR 1578.500					
/ = 1.412					
CORRECTED χ^2 = 1.494					

CAUCASIAN
SPINA BIFIDA

VES.

CAUCASIAN
CONTROLS

PALMS

TEST
MEASUREMENTS

RANK

CONTROL
MEASUREMENTS

RANK

$N_1 = 26$

$R_1 = 1768.5$

$N_2 = 147$

$R_2 = 15282.5$

$U = 2404.500$ OR 1417.500

$Z = 2.095$

CORRECTED $Z = 2.245$

CAUCASIAN
SPINA BIFIDA

VRS.

CAUCASIAN
CONTROLS

PATTERN INTENSITY INDEX, FINGERS

*****				*****			
TEST		RANK		CONTROL		RANK	
MEASUREMENTS				MEASUREMENTS			
*****				*****			
N = 26				N = 147			
S = 2449.0				R = 12402.0			
1				2			
*****				*****			
D = 2090.000				OR 1724.000			
Z = 0.794							
CORRECTED Z = 0.875							
*****				*****			

6

CAUCASIAN
SPINA RIFIDA

VR5.

CAUCASIAN
CONTROLS

PATTERN INTENSITY INDEX, PALMS

TEST MEASUREMENTS

HANK

CONTROL MEASUREMENTS

PANIC

N = 26
1

$$\frac{R}{1} = \frac{2673.5}{1}$$
$$\frac{N}{2} = \frac{147}{2}$$
$$\frac{R}{2} = 12357.5$$

1	=	2342.503	08	1479.500

$$\frac{1}{4} = \frac{1.833}{4}$$

CORRECTED 2 = 2.234

CAUCASIAN
SPI - BIFIDA

VRS.

CAUCASIAN
CONTROLS

MAIN LINE INDEX, D LINE

*****				*****			
TEST		RANK		CONTROL		RANK	
MEASUREMENTS				MEASUREMENTS			
*****				*****			
N = 26				N = 147			
1				2			
R = 2489.5				R = 12561.5			
1				2			
*****				*****			
U = 2138.500				UR = 1683.500			
L = 0.965							
CORRECTED L = 1.279							
*****				*****			

CAUCASIAN
STINA BIFIDA

VRS.

CAUCASIAN
CONTROLS

MAIN LINE INDEX, A LINE

TEST
MEASUREMENTS

RANK

N = 26
1

R = 2962.0
1

CONTROL
MEASUREMENTS

RANK

N = 147
2

R = 12089.0
2

U = 2611.000 OR 1211.000

Z = 2.974

CORRECTED Z = 4.001

MEXICAN SPINA BIFIDA VRS. MEXICAN CONTROLS

FINGERS

TEST MEASUREMENTS RANK

CONTROL MEASUREMENTS RANK

$N = 17$ $R = 547.1$

$N = 86$ $R = 4808.5$

$11 = 1067.500$ OR $394,500$

$Z = 2.989$

CORRECTED $Z = 3.122$

MEXICAN
SPINA BIFIDA

VRS.

MEXICAN
CONTROLS

PALMS

*****		*****	
TEST		CONTROL	
MEASUREMENTS	RANK	MEASUREMENTS	RANK
*****		*****	
N = 17	R = 860.5	N = 86	R = 4495.5
1	1	2	2
*****		*****	
U = 754.500		OR 707.500	
Z = 0.209			
CORRECTED Z = 0.222			
*****		*****	

MEXICAN
SPINA BIFIDA

VRS.

MEXICAN
CONTROLS

PATTERN INTENSITY INDEX, FINGERS

TEST

MEASUREMENTS

RANK

N = 17

R = 1077.5

1

1

CONTROL

MEASUREMENTS

RANK

N = 86

R = 4278.5

2

2

= 924.500 OR 537.500

= 1,719

CORRECTED 2 = 1,085

MEXICAN
SPINA BIFIDA

VRS.

MEXICAN
CONTROLS

PATTERN INTENSITY INDEX, PALMS

*****				*****			
TEST		RANK		CONTROL		RANK	
MEASUREMENTS				MEASUREMENTS			
*****				*****			
N = 17				N = 86			
R = 977.0				R = 4379.0			
1				2			
*****				*****			
U = 824.000				OR 638.000			
Z = 0.826							
CORRECTED Z = 1.069							
*****				*****			

MEXICAN SPINA BIFIDA VRS. CONTROLS

MAIN LINE INDEX, D LINE

TEST MEASUREMENTS RANK

$N = 17$ $R = 1080.0$

CONTROL MEASUREMENTS RANK

$N = 86$ $R = 4276.0$

$U = 927.000$ OR 555.000

$Z = 1.741$

CORRECTED $Z = 1.985$

MEXICAN
SPINA BIFIDA

VRS.

MEXICAN
CONTROLS

MAIN LINE INDEX, A LINE

TEST
MEASUREMENTS RANK

$N = 17$ $R_1 = 1271.0$
 1

CONTROL
MEASUREMENTS RANK

$R_2 = 86$ $R = 4085.0$
 2

$U = 1110.000$ OR 344.000

$Z = 3.438$

CORRECTED $Z = 4.273$

INDIAN
SPINA RIFIDA

VRS.

INDIAN
CONTROLS

FINGERS

TEST
MEASUREMENTS

RANK

N = 9 R₁ = 255.
1

CONTROL
MEASUREMENTS

RANK

N = 74 R₂ = 3231.0
2

= 450.000 OR 210.000

= 1.801

CORRECTED = 1.877

INDIAN
SPINA BIFIDA

VRS.

INDIAN
CONTROLS

PALMS

TEST MEASUREMENTS				CONTROL MEASUREMENTS			
RANK				RANK			
N = 9				N = 74			
1				2			
R = 276.0				R = 3210.0			
L = 435.000				OR 231.000			
Z = 1.494							
CORRECTED Z = 1.585							

INDIAN
 SPINA BIFIDA
 VHS.
 CONTROLS
 PATTERN INTENSITY INDEX, FINGERS

TEST
 MEASUREMENTS
 RANK

N = 9
 R = 387.5
 1

14 = 74
 P = 5998.5
 2

342.500
 322.500

0.139

CORRECTION Z = 0.151

INDIAN
SPINA BIFIDA

VAR.

INDIAN
CONTROLS

PATTERN INTENSITY INDEX, PALMS

*****				*****			
TEST		CONTROL					
MEASUREMENTS		MEASUREMENTS		RANK		RANK	
*****				*****			
N = 9		N = 74		R ₁ = 528.0		R ₂ = 2958.0	
1		2		1		2	
*****				*****			
		U = 423.000		OR		183.000	
		Z = 2.197					
		CORRECTED Z = 2.771					
*****				*****			
*****				*****			

INDIAN
SPINA BIFIDA

VRS.

INDIAN
CONTROLS

MAIN LINE INDEX, D LINE

*****				*****			
TEST		RANK		CONTROL		RANK	
MEASUREMENTS		MEASUREMENTS		MEASUREMENTS		MEASUREMENTS	
*****				*****			
N = 9				J = 74			
1				2			
*****				*****			
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*****				*****			

INDIAN
SPINA BIFIDA

VAR.

INDIAN
CONTROLS

MAIN LINE INDEX, A LINE

*****				*****				*****			
*		*		*		*		*		*	
TEST				CONTROL							
MEASUREMENTS				MEASUREMENTS				RANK			
*****				*****				*****			
*		*		*		*		*		*	
N = 9				N = 71				R = 2803.5			
1				2				2			
*****				*****				*****			

CONTROLS

FINGERS

[illegible]

CLEFT PALATE

VRS.

CONTROLS

PALMS

TEST MEASUREMENTS		RAIRK	
N =	20	R =	569.0
1		1	
U =		441.000	
Z =		0.545	
CORRECTED Z =		0.710	
CONTROL MEASUREMENTS		RAIRK	
N =	40	R =	1261.0
2		2	
U =		359.000	

CLEFT PALATE   VRS.   CONTROLS

PATTERN INTENSITY INDEX, FINGERS

[illegible]

CLEFT PALATE

VRS.

CONTROLS

PATTERN INTENSITY INDEX, PALMS

*****				*****				*****			
TEST		RANK		CONTROL		RANK					
MEASUREMENTS				MEASUREMENTS							
*****				*****				*****			
K = 20		R = 713.0		N = 40		R = 1117.7					
1		1		2		2					
*****				*****				*****			
				U = 505.000				OR 297.000			
				Z = 1.610							
				CORRECTED Z = 2.199							
*****				*****				*****			

CLEFT PALATE

VAR.

CONTROLS

NAIR LINE INDEX, D LINE

*****		*****		*****		*****	
TEST				CONTROL			
MEASUREMENTS		RANK		MEASUREMENTS		RANK	
*****		*****		*****		*****	
N = 20		R ₁ = 738.0		N = 40		R ₂ = 1892.0	
1		1		2		2	
*****		*****		*****		*****	

CLEFT PALATE= VRS. CONTROLS

MATR. LINE INDEX, A LINE

*****				*****			
TEST				CONTROL			
MEASUREMENTS		RANK		MEASUREMENTS		RANK	
*****				*****			
*****				*****			
N = 20		R = 756.		N = 40		R = 1072.	
1		1		2		2	
*****				*****			
*****				*****			
U = 548.000 OR 252.000							
L = 2.321							
CORRECTED L = 3.231							
*****				*****			
*****				*****			

PIERRE ROBIN

VNA.

CONTROLS

FINGERS

*****				*****				*****			
TEST		RANK		CONTROL		RANK					
MEASUREMENTS				MEASUREMENTS							
*****				*****				*****			
N = 10				N = 20				N = 20			
R = 145.0				R = 219.5				R = 219.5			
1				2				2			
*****				*****				*****			
U = 104.500				OR				90.500			
Z = 0.41P											
CORRECTED Z = 0.437											
*****				*****				*****			

PIERRE ROBIN

VRG.

CONTROLS

PALMS

TEST
MEASUREMENTS

RANK

N = 10
1

R = 119.
1

CONTROL
MEASUREMENTS

RANK

N = 20
2

R = 346.0
2

U = 136.000

OR 64.000

Z = 1.584

CORRECTED Z = 1.759

PIERRE ROBIN

VRS.

CONTROLS

PATTERN INTENSITY INDEX, FINGERS

TEST		CONTROL	
MEASUREMENTS	RANK	MEASUREMENTS	RANK
N = 10	R = 158.0	N = 20	R = 299.5
1	1	2	2
U = 110.500 OR 97.000			
Z = 0.462			
CORRECTED Z = 0.495			

PIERRE ROBIN

VRS.

CONTROLS

PATTERN INTENSITY INDEX, PALMS

TEST				CONTROL			
MEASUREMENTS		RANK		MEASUREMENTS		RANK	
*****				*****			
N = 10				N = 20			
1				2			
*****				*****			
R = 189.5				R = 275.5			
*****				*****			
= 134.500				= 65.500			
= 1.516				= 1.516			
CORRECTED = 1.789				CORRECTED = 1.789			
*****				*****			

PIERRE BOBIN

VRS.

CONTROLS

MAIN LINE INDOX, D LINE

TEST

MEASUREMENTS

RAZK

CONTROL

MEASUREMENTS

$$f(x) = \frac{1}{2} \left(|x| + \sqrt{x^2 + 4} \right)$$

N = 10

$$R = 157.9$$

21

R = 302.0

198,070

٤١٤

97,500

$$\lambda = 0,552$$

CORRECTED: $\frac{1}{2} = 0.543$

PIERRE ROBIN

VRS.

CONTROLS

MAIN LINE INDEX: A LINE

TEST		CONTROL	
MEASUREMENTS	RANK	MEASUREMENTS	RANK
$N_1 = 10$ $R_1 = 164.0$		$N_2 = 20$ $R_2 = 361.0$	
$= 109.000$ OR 91.000			
$= 0.395$			
CORRECTION = 0.535			