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Dermatoglyphic Variability in Armenian Fingertips and Palms: A Directional Asymmetry Approach to Identify Developmental Stress

Cleone Hart Hawkinson
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To the Graduate Council:

I am submitting herewith a thesis written by Cleone Hart Hawkinson entitled "Dermatoglyphic Variability in Armenian Fingertips and Palms: A Directional Asymmetry Approach to Identify Developmental Stress." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Anthropology.

Richard L. Jantz, Major Professor

We have read this thesis and recommend its acceptance:

William M. Bass, Fred H. Smith

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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

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Vice Chancellor
Graduate Studies and Research

A

DERMATOGLYPHIC VARIABILITY IN ARMENIAN FINGERTIPS AND PALMS: A DIRECTIONAL ASYMMETRY APPROACH TO IDENTIFY DEVELOPMENTAL STRESS

A Thesis

Presented for the

Master of Arts

Degree

The University of Tennessee, Knoxville

Cleone Hart Hawkinson

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DEDICATION

To the extraordinary teachers in my life, thank you.

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ABSTRACT

The dermatoglyphic variability of the fingertips and palms of an Armenian sample was investigated. The sample consisted of 228 stressed and unstressed individuals. Prenatal stress due to severe physical and nutritional deprivation was not recorded in the developing dermal ridge system in the form of increased directional asymmetry or variation in ridge breadth. No intergenerational effect of stress on the dermal ridge system was identified. A new palmar variable, b-c ridge breadth, was developed and incorporated into the analysis.

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INTRODUCTION

This thesis explores the hypothesis that prenatal stress due to severe physical and nutritional deprivation is reflected in a developing finger and palmar dermal ridge system. The samples used to test this hypothesis were drawn from a common gene pool, a known portion of which had undergone severe stress. The hypothesis is that the stressed portion of the sample will exhibit different dermal ridge relationships than the unstressed portion of the sample. This analysis will identify these differences if they exist. The role of directional asymmetry as a measure of prenatal stress is assessed. As background for understanding the analysis, the prenatal development of the dermal ridge system, the concept of directional asymmetry, and some effects of prenatal stress are discussed.

CHAPTER I

BACKGROUND

The dermal ridges of fingertips and palms are a useful and readily obtainable source of information for those interested in human variation. Dermatoglyphic data are well suited to test prenatal development models because they represent a limited and specific period of fetal development, and remain unchanged except for size throughout life. Generally, dermal ridges are considered to be the result of polygenic systems, although the precise components of these systems have not yet been identified.

Several approaches have been taken to try to understand the variation expressed within this system. In addition to the descriptive and population studies by anthropologists, genetical studies have been designed to estimate heritibility (Froehlich, 1976; Holt, 1968; Loesch, 1971), to investigate the implications of twinning (Reed, Sprague, Kang, Nance, and Christian, 1975; Reed, Uchida, Norton, and Christian, 1978), as well as to identify relationships to chromosomal abnormalities and other clinical syndromes (see Mavalwala, 1977, for a topical index).

The influence of environmental factors has been studied in terms of asymmetry (Holt, 1954; Singh, 1970), maternal effects (Reed, Evans, Norton, and Christian, 1979), and developmental disturbances of a nongenetic nature, for example congenital rubella (Purvis-Smith and Menser, 1978). Implicit in these studies is the assumption that the

environment alters the path of normal development, thus accounting for the phenotypic variation which exists within the individual.

Considerable attention has been directed to the prenatal development of dermal ridges (Hale, 1952; Babler, 1977, 1978, 1979, 1980; Mulvihill and Smith, 1969; Okajima, 1975). The developmental sequence of ridge formation has been identified histologically for the right hand in Whites and Blacks (Babler, 1977). However, the right hand's developmental relationship to the left can only be hypothesized. In this regard, laterality studies provide useful insights (Corballis and Morgan, 1978; Mittwoch, 1977).

Okajima (1979) conducted a histological investigation of volar skin sturctures in an adult Japanese sample. However, ridge relationships below the skin surface after growth has ceased have yet to be quantified. Clarification of these relationships, taking sex and race into account, would greatly enhance our understanding of developmental processes.

At present we are limited to the information contained on the skin surface to identify existing variation within and between groups. The developmental interpretation of this variation can only be inferred until more information becomes available. However, this limitation does not prevent active inquiry into the nature and timing of growth gradients, and the testing of such developmental hypotheses as that proposed by Jantz and Webb (1980).

Their conclusion depends on a mixture of empirical data and reasonable inferences about observed relationships. One assumption is that the finger patterns are related to the size and shape of the

fetal pad during the time of ridge formation (Mulvihill and Smith, 1969; Babler, 1980). Finger pattern type and size have been related to the shape of the terminal phalanx which underlies the fetal pad (Katzenmaier, 1979). Furthermore, Babler (1978) has established that the type of pattern is dependent upon the timing of ridge formation in relation to pad regression. He found that abortuses with early ridge formation had a high percentage of whorls. Those with later ridge formation had more arches.

The relationship of ridge width to growth rates remains unclear. Jantz (1978) suggested that ". . . ridge width may be related to rates of fetal growth, narrower ridges resulting from faster growth (Barlow, 1973)." However, rubella insult patients with known delayed growth in utero, exhibit a high frequency of whorls (Purvis-Smith and Menser, 1978). Turners syndrome females, believed to have a depressed growth rate, have small distal phalanges, short stature, but very fine high count finger ridge patterns. One explanation is that the pad regression is delayed in relation to ridge formation. Typologically, a high pad induces a whorl configuration (Mulvihill and Smith, 1969).

Babler has expressed the opinion that variation in the depth of the primary ridge will yield important imformation beyond that contained in traditional ridge-counts on the skin surface (Personal Communication). He found epidermal ridge dimensions are highly correlated with specific skeletal and dermal dimensions. For example, the width of primary ridges has a high positive correlation with the length of the distal phalanx. The thickness of the dermis is correlated with the inter-ridge distance (Babler, 1980). As the

information about the primary ridge depth and dermal thickness is unavailable from skin surface observation, we must await further histological studies. The two approaches investigate different but related aspects of the same system. While ridge-counts may be a crude estimate, meaningful variation is detectable.

Another assumption is that pads normally begin to regress on the ulnar side of the finger (Jantz, Personal Communication). The resulting temporary pad asymmetry produces the most common pattern, the ulnar loop, provided ridge formation is occurring at this time. Departures from this condition have important implications for postulating developmental gradients.

In summary, the variables affecting any one finger include the timing of ridge formation and pad regression, and the particular size and shape of the fetal pad when each event takes place. Fingers also have growth relationships across the hand, and between hands.

One such gradient, across the hand, has been established although sex differences exist in the intensity and expression of this gradient. Development crosses the hand in a radial-ulnar direction. Ridge formation has been shown to follow this pattern (Babler, 1977). Radial-ulnar gradients emerged from factor analysis of ridge-counts even before Babler confirmed this in the laboratory (Jantz and Owsley, 1977; Roberts and Coope, 1975).

The developmental relationship between hands has not yet been established. The left hand may precede the right hand slightly, although there is not direct evidence for this dermatoglyphically. Several developmental systems are known in which the left precedes the

right in development (Corballis and Morgan, 1978).

Sex differences further complicate the identification of normal developmental patterns. Normal males and females are known to differ in their developmental timing of intrauterine growth. Considerable evidence suggests that males undergo faster intrauterine growth than females (Garn, Burdi, and Babler, 1974; Mittwoch, 1971; Ounsted, 1972). The accelerated male growth may also apply to the ridge system as well. The result is that males and females show clearly different patterns of asymmetry for finger ridge-counts, independent of predictable size differences. These different patterns suggest that different growth gradients occur for males and females.

Racial variation in dermal ridge development has been demonstrated for Black males, who have slower ridge maturation for crown-rump length than Whites (Babler, 1977). Asymmetry differences have also been noted for ridge-counts in which Blacks are less asymmetrical than Whites (Jantz and Webb, 1980). Ridge breadth in the a-b interdigital area of the palm was found to be significantly greater in the Yoruba, a Black African group, than in comparative White samples (Jantz and Parham, 1978).

Departures from the normal number of sex chromosomes have marked effects on growth rates. Studies suggest extra Y chromosomes will accelerate growth. As adults, 47,XYY males are tall, greater than 72 inches (Moody, 1975), and have long distal phalanges (Burdi, 1980). They have large teeth with thick enamel (Alvesalo, Osborne, and Kari, 1975). Alvesalo and Kari (1977) state the factors affecting excess dental growth are working continuously from early fetal life, beginning the seventh or eighth week in utero. This excessive growth

would overlap the period of dermal ridge development, and may be reflected by increased asymmetry and palmar ridge breadth.

Turners syndrome females (XO) lack one X or a Y chromosome and have smaller than average teeth, thinner enamel (Alvesalo, 1980), and short stature, generally not exceeding 57 inches (Moody, 1975). They exhibit decreased asymmetry and palmar ridge breadth.

Jantz and Webb (1980) have found that asymmetry in finger ridge-counts is systematically affected by alteration in the number of sex chromosomes. A Y chromosome has twice the effect of an X chromosome in their Generalized Asymmetry Score (GAS). The XO and 47,XYY samples are at opposite extremes of this asymmetry distribution. In the a-b interdigital area of the palm, additional sex chromosomes increase ridge breadth values above the normal mean. The absence of a sex chromosome diminishes ridge breadth (Penrose, 1969).

Jantz and Webb (1980) also found racial differences in the GAS for normal Blacks and Whites. While one cannot argue directly from asymmetry scores or ridge breadth to growth rates, the important point is that dermatoglyphic asymmetry is clearly patterned.

This patterning has important implications for the use of asymmetry as a measure of environmental stress. Fluctuating asymmetry, minor random variation about a zero mean, is distinguished from directional asymmetry, a systematic bias to one side (Van Valen, 1962). Fluctuating asymmetry has been frequently used as a measure of environmental stress, especially in dental studies (Bailet, Workman, Niswander and MacLean, 1970; Garn, Lewis, and Kerewsky, 1966, 1967; Perzigian, 1977; Webb, 1977). The argument is that the genotype should

be identical for both sides in a bilaterally symmetrical organism (Adams and Niswander, 1967). Homologous structures should be alike unless environmental factors interfere with development. Departures from symmetry are thus interpreted as an indication of such interference. The greater the asymmetry, the lower the ability to withstand stress, or even perhaps, the greater the stress. If no asymmetry is detected, the homologous structures are considered unaffected by stress. In these studies directional asymmetry is presumed to be non-existent. If a side bias is encountered, correction factors are applied to eliminate the bias.

Clearly, this is not a reasonable approach for developing hands, if one is also postulating growth gradients across the hand, and between hands. Homologous digits may have the same genotype, but the timing of their development may be slightly different, i.e. the relationship of ridge formation to pad regression. The argument has been made that differences in the amount of dermatoglyphic asymmetry may in fact be a reflection of differences in developmental timing (Jantz, 1978). For widely diverse groups, identifiable sex and race patterning exists in dermatoglyphic asymmetry (Jantz, 1975, 1978). Therefore, such patterning is not likely to be brought about by stress, but differing systemic relationships during ridge formation. In addition, differences may exist in the ability to withstand developmental insult, as well as the actual timing of developmental events.

New insights may be gained by looking for directional patterning in asymmetry relationships across a developmental field. In doing so,

directional asymmetry should provide useful information in identifying growth relationships lost when fluctuating asymmetry is used. Departures from these relationships might then suggest environmental interference.

In summary, dermal ridge development follows a growth gradient which procedes along a normal pathway. The asymmetry of homologous digits is patterned in a way which reflects these growth relationships. Departures from this pattern might be attributed to environmental stress. The problem is to identify normal developmental patterns, taking sex and race into account, and then to test hypotheses of stress.

The effects of prenatal stress may not be confined to the developing fetus. Weinstein (1978) has found evidence of a lingering intergenerational effect for chronic malnutrition and accompanying physical deprivations in his Mexican samples. His studies show that a mother's own developmental environment can affect her pregnancies and the future of her offspring. This has important implications for our sample because a portion of it consists of children of stressed individuals. It remains to be demonstrated, of course, that the intergenerational effects carry over in the dermal ridge system.

The Problem

This study will test the assumption that the effects of stress are recorded in the dermal ridge system. One way to try to identify the presence of stress in dermal ridge development is to investigate a genetically similar sample, a segment of which has undergone severe stress. The Armenian data collected by Dr. Richard L. Jantz in

Australia, during 1979, meet this criterion. This thesis proposes to explore the dermatoglyphic variation within this sample of Armenians. The hope is to identify the typical Armenian patters of development, and to test the stressed sample for departures from these patterns.

CHAPTER II

MATERIALS AND METHODS

The Sample

The sample consists of finger and palmar prints of Armenians residing in Sydney, Australia, in 1979. All dermatoglyphic data were collected by Richard L. Jantz. According to Kirkland (1980) the Armenians migrated to Australia largely because of political changes after World War II. The sample may be divided into two groups, a West and an East group, based upon geographical origin.

The West group consists of the majority of Armenians who came from Arab countries and whose parents were born in Turkey. They are the children, therefore, of former refugees from the massacres of World War I. Some of the older immigrants are refugees themselves. Therefore, the West sample includes those actually stressed in utero, or those whose parents or grandparents were stressed. If stress is recorded in the dermal ridge system, the evidence of stress should be most marked in the oldest individuals. The intergenerational effects, if they exist in the dermal ridge system, might be expected to be present in their offspring.

Armenians coming from Iran, or daughter communities in south and east Asia, are designated as the East group. They are generally from a relatively secure social and economic background (Kirkland, 1980). They represent the unstressed portion of the sample. Their finger and palmar ridge relationships will be considered the typical pattern for Armenians.

The sample may be further divided by identifying children born in Australia. The children born to parents from the West sample represent the "grandchildren" of the stressed generation. Born in the nutritionally and physically unstressed environment of Australia, they might be expected to differ from the representatives of the parent and grandparent generations.

A summary of the various subsamples is provided in Table 1. Unfortunately the sample sizes for children born in Australia of East parents is too small for meaningful comparison. The samples of children born outside Australia of East and West parents are also too small. These individuals are grouped with the appropriate adult groups for finger analyses. Palmar measurements for all children (less than 16 years) were analysed separately in the ridge breadth portion of the analysis.

The Methods

I counted the finger and palm ridge-counts according to methods described by Holt (1968). Twenty finger ridge-counts were recorded for each individual. For three individuals, two missing counts were predicted by regression analysis.

Palms were evaluated as follows. The a-b, b-c, and c-d interdigital ridge-counts were recorded (Baitsch and Schwarzfischer, 1959). In addition, the distances for the a-b and b-c interdigital areas were measured using a dial caliper. These measurements were recorded in hundredths of a millimeter. Traditionally only the a-b

TABLE 1. Description of the Sample.

Finger Ridge-counts	N
Total sample	224
Males	123
East born	41
West born	82
Adults	63
Australian born boys	19
Females	101
East born	37
West born	64
Adults	47
Australian born girls	17

Palmar Data	
Total sample	228
Males	125
East born	42
Adults	34
Australian born boys	5
East born boys (16 years)	3
West born	83
Adults	58
Australian born boys	21
West born boys (16 years)	4
Females	103
East born	38
Adults	32
Australian born girls	3
East born girls (16 years)	3
West born	65
Adults	46
Australian born girls	17
West born girls (16 years)	2

distance has been measured for calculation of ridge breadth (Penrose and Loesch, 1967). The area is considered appropriate because ridges are generally perpendicular to the line of count.

My observation, however, was that the a-b area is quite variable in size. In very broad a-b areas, ridges often depart quite dramatically from perpendicularity. In addition, the variation in density of ridges within a large a-b area was often great, with closely spaced ridges at either edge, widely separated ridges in the central area. As a-b distances increases, the calculation of ridge breadth becomes increasingly crude. The b-c area seemed considerably smaller in size, and ridges appeared to be more uniform across the line of count. The perpendicularity of ridges is as good as in the a-b area.

The argument has been made that the a-b area has fewer patterns than the b-c area. My observation was that while more patterns do appear in the b-c area, they are generally well below the line of count, so they have very little effect. Those patterns in the a-b area fall within the line of count, almost without exception. Their interference is considerably more marked.

Thus the b-c area also seemed to be appropriate for calculating ridge breadth. Further, the relationships of the a-b and b-c ridge breadths could be explored. The inclusion of the b-c measurement will be viewed as an experiment to see if additional information is gained by expanding traditional methodology.

Missing c triradii were estimated by the method described by Baitsch and Schwarzfischer (1959) for ridge-counting. A point was

identified eleven ridges below the midpoint of the junction of the middle finger and palm. This point was considered the c triradius. Ridge-counts and the b-c measurement were recorded from this reference point. Tabulation of the frequency of missing c triradii for each group is presented in Table 2.

In general, missing c triradii may be handled in three ways. Individuals with missing c triradii may be deleted from the sample. The result is a reduced sample size, not a desirable solution when data are limited. This method has the further disadvantage of loss of any relationships associated with the missing c triradius. Second, these individuals may be included, but variables involved with the c triradius are deleted for that individual. These missing observations make statistical manipulations more complicated. Finally, one may estimate the position of the c triradius, as described above. The sample size is maintained, and the observations are complete for each individual.

Ridge breadth was calculated as described by Penrose and Loesch (1967). The distances for the a-b interdigital areas for both hands were summed and divided by the corresponding summed ridge-counts plus two. The summed value was obtained to be compatible with literature data for future studies. The a-b ridge breadth for each hand was also retained for analysis (distance/ridge breadth plus one). This insured individuality of hands would not be lost by summing.

Ridge breadth was calculated for the b-c area as well. To my knowledge, no comparable literature data exist for this measurement. Summed values and individual hand values were obtained for the analysis.

TABLE 2. Frequencies of Missing C Triradius.

	Left	Right	Left+Right	% Total
East males n=42	2[a]	0	2	7.1
East females n=38	0	0	2[a]	5.3
West males n=83	3[a]	1	0	2.4
West females n=65	4[b]	1	0	3.8

[a] includes one child

[b] includes two children

Age, in hundredths of a year, was recorded for each individual in the sample. This was accomplished by subtracting the exact birth date from the date the prints were collected, using the table provided in Weiner and Lourie (1969:32).

All statistical analyses were done on the IBM 370 computer at the University of Tennessee Computing Center. SPSS and SAS statistical package programs were used. Specialized programming assistance was provided by Stuart W. Hawkinson.

CHAPTER III

FINGER RIDGE-COUNT ANALYSIS

Twenty Finger Ridge-Count Variables

The analysis of the twenty finger ridge-count variables began by calculating the means and standard deviations for each group by sex. These are presented in Table 3. A few brief observations can be made on the relationships between the group means. In general, the West males have higher ridge-count means than East males, except for the thumb counts and right ulnar digit 2. The West females have higher means than the East females for every count except for the right ulnar thumb count. Finally, the East females had all ulnar loops on right digit 3. To explore this variation, principal components analysis, followed by Multiple Analysis of Variance, was used as the method of analysis.

First, a within-groups correlation matrix, based on 212 degrees of freedom, was calculated to be used in the principal components analysis. Grand means and standard deviations were calculated for use in obtaining standard scores.

Principal components were calculated using the SPSS subroutine FACTOR. Ten unrotated components were obtained. The first six eigenvectors, along with their corresponding eigenvalues are presented in Table 4. The components are similar to those found in previous analyses (Roberts and Coope, 1975; Jantz and Owsley, 1977; Jantz and Hawkinson, 1980).

The first component is size, with high positive loadings,

TABLE 3. Finger Ridge-count Means by Group and Sex.

	WEST				EAST			
	Males n=82		Females n=64		Males n=41		Females n=37	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.
L5R	15.10	4.49	14.11	5.84	14.22	6.03	12.08	5.47
L5U	2.89	5.45	2.41	4.57	1.63	3.86	1.81	3.99
L4R	17.72	5.93	15.13	7.85	15.56	5.78	12.97	6.61
L4U	8.21	8.02	6.80	7.43	5.24	6.75	3.92	5.72
L3R	13.44	5.82	11.66	7.54	10.66	6.83	9.73	7.06
L3U	4.38	8.05	5.19	8.13	2.90	6.10	2.08	4.90
L2R	10.42	6.96	8.45	7.25	10.07	7.54	6.89	6.85
L2U	9.21	8.68	8.06	9.09	8.39	8.20	5.70	8.10
L1R	18.81	6.98	15.97	6.22	19.02	5.97	15.22	6.57
L1U	6.29	7.56	7.78	8.40	9.78	9.06	7.30	7.71
R5R	14.65	4.59	12.98	5.82	14.37	5.25	11.70	5.58
R5U	3.17	5.16	1.80	4.16	1.27	3.26	1.22	3.16
R4U	17.17	6.19	14.80	7.20	15.98	6.14	13.43	6.61
R4U	8.13	7.53	6.88	7.30	5.98	7.83	5.70	6.46
R3R	12.88	5.50	12.03	6.31	11.43	6.44	10.54	6.25
R3U	4.18	7.43	3.94	7.58	2.63	5.86	0.00	0.00
R2R	10.44	6.83	9.36	7.47	8.34	7.19	8.57	6.64
R2U	8.70	8.76	7.55	8.39	8.98	7.77	7.00	7.72
R1R	20.27	6.44	17.09	6.32	20.42	5.22	16.73	5.88
R1U	8.85	8.62	7.44	8.17	10.71	9.18	8.05	7.90

TABLE 4. First Six Principal Components of the Twenty Finger Ridge-counts.

	Components 1	2	3	4	5	6
L5R	0.782	-0.223	0.032	-0.018	-0.362	0.170
L5U	0.544	0.448	-0.165	0.503	-0.094	-0.081
L4R	0.830	-0.144	-0.001	-0.238	-0.235	-0.065
L4U	0.726	0.315	-0.134	0.082	-0.123	-0.217
L3R	0.781	-0.091	-0.242	-0.240	0.179	-0.180
L3U	0.652	0.479	0.155	-0.091	0.170	0.143
L2R	0.689	-0.065	-0.334	-0.091	0.267	0.081
L2U	0.664	0.117	0.452	-0.135	0.083	-0.030
L1R	0.661	-0.499	-0.106	0.269	0.114	0.204
L1U	0.621	-0.167	0.426	0.369	0.145	-0.266
R5R	0.761	-0.228	0.047	-0.048	-0.407	0.108
R5U	0.506	0.459	-0.301	0.405	-0.213	0.118
R4R	0.821	-0.131	0.009	-0.204	-0.210	-0.103
R4U	0.740	0.280	-0.101	-0.056	-0.126	-0.152
R3R	0.810	-0.140	-0.136	-0.223	0.141	-0.194
R3U	0.603	0.474	0.118	-0.169	0.251	0.419
R2R	0.703	-0.100	-0.312	0.064	0.388	-0.135
R2U	0.663	0.143	0.352	-0.315	-0.006	0.080
R1R	0.626	-0.480	-0.152	0.230	0.081	0.298
R1U	0.521	-0.144	0.557	0.409	0.121	-0.041
Eigenvalue	9.569	1.786	1.327	1.230	0.908	0.647
Variation	47.8%	8.9%	6.6%	6.2%	4.5%	3.2%

reflecting the positive correlation between all variables. This component accounts for 47.8% of the total variation. The second component contrasts the radial and ulnar counts, except the ulnar thumb. This component accounts for 8.9% of the variation, and indicates a negative interaction between the sides of the finger, after the effects of size have been removed. Component 3 reveals an ulnar gradient, with negative loadings on digits 5 and 4. Positive loadings increase as the gradient crosses the hand to digit 1, the thumb.

Component 4 shows strong positive loadings for the ulnar counts of digit 5, as well as both sides of the thumb. This component accounts for 6.2% of the variation. Component 5 contrasts digits 4 and 5 with digit 3 and the radial counts of digit 2. While the eigenvalue is less than one, this component was retained in the analysis because past experience has shown significant between group heterogeneity on the later components (Jantz and Hawkinson, 1980). This component accounts for 4.5% of the variation.

Component 6, which accounts for 3.2% of the variation, is less easily interpreted. On both hands, the radial and ulnar sides of the thumb are contrasted. In addition, the ulnar side of digit 3 on the right hand has a strong positive loading. The amount of variation accounted for by these six components is 77.2%.

Standard scores were calculated and used in a Multiple Analysis of Variance. Group, sex, and group-sex interaction were the treatments for the model. The results of this analysis are presented in Table 5. The overall model had significant group and sex differences.

TABLE 5. Multiple Analysis of Variance of Finger Ridge-count Components.

Full Model

	F	p
Group	1.96	.0399
Sex	2.41	.0099
Group*Sex	ns	

F is calculated from Wilks' Lambda

Univariate

Component	F	p	Type IV Sum of Squares	
1	3.11	.027	Group .05;	Sex .02
2	3.19	.024	Group .03;	Sex .03
3	2.51	.058	Group .04	
4	0.74	ns		
5	1.31	ns		
6	3.90	.009		Sex .002
7	0.67	ns		
8	0.92	ns		
9	1.51	ns		
10	0.87	ns		

However, interaction between group and sex was not significant. The univariate F's are presented to identify which components contributed to the overall model.

Components 1 and 2 were significant for group and sex. Inspecting the means of these components clarifies these relationships (Table 6). Component 3 is significant only for group. The East males and West males are quite different from each other. Component 6 is significant for sex. For this component, the East males and East females are very different from each other.

To identify further variation in finger ridge-count relationships, and to test the hypothesis of stress, directional asymmetry is explored in the next segment of the analysis.

Ten Asymmetry Variables

Ten asymmetry variables were calculated from the raw data of the twenty finger ridge-count variables. The right minus left ridge-count was calculated for the radial and ulnar sides of homologous digits. For example, asymmetry variable one was the radial count for right digit 5 minus the radial count for left digit 5. The means and standard deviations for the ten asymmetry variables are presented by group and sex in Table 7.

Regression analysis was performed on the ten asymmetry variables with age as the dependent variable. The asymmetry variables were regressed separately by sex for each group. The results are presented in Table 8.

The purpose of the regression analyses was to identify a significant relationship between asymmetry variables and age. The

TABLE 6. Principal Component Means Calculated from Finger Ridge-counts.

Component	West Male n=82	West Female n=64	East Male n=41	East Female n=37
1	0.213	-0.059	0.004	-0.381
2	-0.002	0.247	-0.374	-0.002
3	-0.209	0.047	0.299	0.058
4	-0.053	-0.096	0.155	0.109
5	-0.167	0.111	0.040	0.142
6	0.165	-0.114	0.221	-0.421

TABLE 7. Ten Asymmetry Variable Means.

	WEST				EAST			
	Males n=82		Females n=64		Males n=41		Females n=37	
R-L	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.	$\bar{X}$	S.D.
5R	-0.451	3.29	-1.125	3.20	0.146	4.07	-0.378	3.26
5U	0.281	4.45	-0.609	2.87	-0.366	4.19	-0.595	2.74
4R	-0.549	3.57	-0.328	4.86	0.415	3.51	0.459	4.86
4U	-0.073	5.21	0.078	4.15	0.732	7.16	1.784	6.02
3R	-0.561	3.67	0.375	4.54	0.683	5.46	0.811	3.00
3U	-0.195	6.21	-1.250	5.05	-0.268	4.88	-2.081	4.90
2R	0.024	6.23	0.906	6.08	-1.732	5.99	1.676	6.46
2U	-0.512	6.51	-0.516	8.27	0.585	6.91	1.297	8.16
1R	1.463	4.88	1.125	4.05	1.390	3.77	1.514	4.83
1U	2.561	6.94	-0.344	6.52	0.927	6.76	0.757	7.42

TABLE 8. Regression Analysis: Age*Ten Asymmetry Variables.

	Model			
	F	p	r	df
West Males n=82	0.42	0.93	0.056	10,81
East Males n=41	1.27	0.29	0.297	10,40
West Females n=64	1.49	0.17	0.220	10,63
East Females n=37	0.50	0.87	0.162	10,36

hypothesis was that increased asymmetry would be positively correlated with the older individuals in the stressed (West) groups. The analyses did not support this hypothesis. The full model F's were not significant for either West males or females. Further, neither group showed significant asymmetry regressions for individual variables. The regression analyses were also not significant for the full model for either East group.

The correlation for each is very low. The regression equations explain only 5.6% of the West male variation, 22% of the West female variation. The East male group is a bit higher with 29.7%, but only 16.2% for females. Bivariate plots of each asymmetry variable with age do not provide any further insights.

A Multiple Analysis of Variance of the ten asymmetry variables was performed to identify the source of variation. Sex, group, and sex-group interaction were the three treatments in the model. The results are presented in Table 9. The full model is not significant for any treatment. However, the univariate test for asymmetry variable 7 (radial 2) is significant. Sex and sex-group interaction are significant for identifying the variation of this variable. Referring back to Table 7, and inspecting the means for radial 2, the East males are -1.73, the East females are 1.68. The West means are both positive and intermediate.

At this point in the analysis, the hypothesis that stress is associated with increased directional asymmetry in the finger ridge-counts cannot be accepted.

TABLE 9. Multivariate Analysis of Variance of Ten Asymmetry Variables.

Full Model

	F	p	df (10,211)
Group	1.29	0.24	
Sex	1.49	0.15	
Group*Sex	0.94	0.50	

F is calculated from Wilks' Lambda

Univariate

Asymmetry (R-L)	F (df 3,223)	p	Type IV Sum of Squares
1 (radial 5)	1.89	0.13	Group .04
2 (ulnar 5)	0.91	0.44	ns
3 (radial 4)	1.00	0.39	ns
4 (ulnar 4)	0.95	0.42	ns
5 (radial 3)	1.56	0.20	ns
6 (ulnar 3)	0.48	0.70	ns
7 (radial 2)	2.60	0.05	Sex .02; Group*Sex .05
8 (ulnar 2)	0.93	0.43	ns
9 (radial 1)	0.34	0.80	ns
10 (ulnar 1)	1.47	0.22	ns

Two Asymmetry Variables

Two composite asymmetry variables were calculated to explore further the relationships between the East and West groups. By reducing the hand's ten variables to two, the combined variable differences might be great enough to distinguish between the groups. Jantz and Webb (1980) found this general approach useful for enhancing sample differences.

Reduction in the number of variables for each hand was accomplished by combining the radial counts (2-5) into one variable, and the ulnar counts (1-5) plus the radial thumb, into a second variable. These choices result from the discriminant loadings found by Jantz and Webb (1980). The right minus left difference for each variable was then obtained.

Each new variable was then regressed on age. The hypothesis was that a significant correlation would exist between age and the level of asymmetry. The results by sex and group, are presented in Table 10, along with their means and standard deviations. No significant association was found between age and level of asymmetry for any group. Bivariate plots of age with each asymmetry variable showed random scattering of points.

A Multivariate Analysis of Variance was then used to evaluate group, sex, and group-sex interaction. The full model was not significant for any treatment. Neither univariate F was significant. No differences were found for group or sex for the composite asymmetry variables. The composite asymmetry variables did not enhance the differences between the groups.

TABLE 10. Regression Analysis: Age*Two Asymmetry Variables.

	F	Model p	r	df
West males n 82	0.18	0.84	0.004	2,81
East males n 41	0.65	0.53	0.033	2,40
West females n 64	0.84	0.44	0.027	2,63
East females n 37	1.29	0.29	0.071	2,36

Asymmetry Variable Means and Standard Deviations.

	Asymmetry 1		Asymmetry 2	
	$\overline{X}$	s.d.	$\overline{X}$	s.d.
West males	-1.537	8.50	3.524	18.39
East males	-0.488	10.51	3.000	13.64
West females	-0.172	9.92	-1.516	16.40
East females	2.568	8.56	2.676	20.90

Comparison of Two Asymmetry Variables with Other Groups

Finally, the Armenian asymmetry variables were placed into a context by comparing them with other groups. Comparative data were limited by the availability of raw data. Four groups were chosen to compare with the two Armenian samples: Germans, University of Tennessee white students, Greeks, and Hancock County residents.

The Germans and University of Tennessee students represent reference Caucasian samples. The German data were collected by Mr. Heinz Brehme in the Freiburg area. The University of Tennessee students were volunteers from the Introductory Anthropology classes.

The Greeks (Brehme and Pentzos-Daponte, 1975) are genetically the most closely related group available. The Hancock County data represent, as nearly as possible, a group which may be considered nutritionally or physically stressed. These data, as yet unpublished, include elementary school age children and unrelated adults, collected by Dr. Richard L. Jantz.

The two composite asymmetry variables were calculated for each of these groups. Descriptive statistics were calculated, as well as the correlation between the two asymmetry variables for each group. This information is presented in Table 11.

The groups had the same rank order for increasing negative correlation for both males and females. The East Armenians and Greeks had the lowest negative correlation. The Germans and U.T. Whites were intermediate. The West Armenians and Hancock County residents had the strongest negative correlations between the two asymmetry variables.

TABLE 11. Comparative Groups: Two Asymmetry Variable Means, Standard Deviations, and Correlations.

Group	Asymmetry 1		Asymmetry 2		r
	$\bar{X}$	s.d.	$\bar{X}$	s.d.	
Males					
East Armenian n=41	-0.488	10.507	3.000	13.635	-0.1297
Greeks n=143	-0.972	8.896	7.909	19.134	-0.1754
Germans n=154	-2.812	11.176	10.799	19.043	-0.2386
U. T. Whites n=398	-0.339	9.874	8.427	15.608	-0.2962
West Armenian n=82	-1.537	8.502	3.524	18.394	-0.3635
Hancock County n=47	-1.872	9.502	6.532	14.788	-0.4092
Females					
East Armenian n=37	2.568	8.562	2.676	20.902	-0.1357
Greeks n=124	-0.419	9.021	2.065	17.961	-0.2087
Germans n=151	0.934	9.873	3.311	15.851	-0.2199
U. T. Whites n=431	1.773	10.609	4.884	15.413	-0.2232
West Armenian n=64	-0.172	9.921	-1.516	16.395	-0.2714
Hancock County n=63	1.333	9.859	0.476	14.888	-0.3723

The correlations were tested, but were not found to be significantly heterogeneous. The highest negative correlations for the two stressed groups were interesting, however, especially because this was true for both sexes.

Four one way Analyses of Variance were calculated to test the hypothesis that a difference existed between the group means. The results for each variable, by sex, are presented in Table 12. The differences between the group means for the first variable for males were not significant. The other three variables each had significant group mean differences.

The Scheffe procedure (Scheffe, 1959), a post hoc evaluation of the means, identified which means contributed to the variation for the significant variables. Briefly, the means were ranked in order, and the highest tested against the lowest for significant difference. For example, for the males, asymmetry variable two (sum of the ulnar counts plus the radial thumb), was tested. The Germans have the highest mean, the East Armenians have the lowest (see Table 11). No significant difference was found between these two means, so no other combination of two means could be significantly different.

Combinations of more than two means were then tested. The Scheffe procedure dictates the method of combining the means. The hope was to identify biologically meaningful combinations of means. The result of this Scheffe procedure grouped the Germans and U.T. White means together as different from the group means of Hancock County residents, West and East Armenians. The Greek mean was not different from either of these groups.

TABLE 12. Analysis of Variance: Two Asymmetry Variables with Six Groups.

	F	df	p
Males			
Asymmetry 1 R(2-5)	1.939	5,860	ns
Asymmetry 2 U(1-5)+R1	4.741	5,860	.01
Females			
Asymmetry 1 R(2-5)	2.258	5,865	.05
Asymmetry 2 U(1-5)+R1	2.364	5,865	.05

The test for the first female asymmetry variable (radial 2-5) grouped the East, U.T. Whites, and Hancock County means, and the Germans, Greeks, and West means. The second variable grouped U.T., German, and East means and the Greek, West, and Hancock County means. Since no clear biologically relevant groups emerged, little interpretation in terms of stress can be offered.

In summary, the only interesting relationship uncovered by comparing the Armenians to other groups was the high negative correlation for the West and Hancock County asymmetry variables.

CHAPTER IV

PALMAR RIDGE-COUNT ANALYSIS

Principal Components: East vs West

The analysis of the six palmar ridge-count variables began by calculating the means and standard deviations for each group by sex. These are presented in Table 13. No significant differences were found between the group means for any variable. A within-groups correlation matrix, based on 216 degrees of freedom, was calculated for use in the principal components analysis. Grand means and standard deviations were calculated for use in obtaining standard scores. This information is presented in Table 14.

Principal components were calculated using the SPSS subroutine FACTOR. Six unrotated components were obtained. These six eigenvectors, along with their corresponding eigenvalues are presented in Table 15.

The first component reflects size, with high positive loadings. This component accounts for 52.2% of the total variation. The second component contrasts the a-b counts, having strong positive loadings, with the b-c counts which have strong negative loadings. This component accounts for 21% of the variation. Component 3 accounts for 14.8% of the variation, with the c-d count having strong negative loadings.

Components 4 through 6 account for the remaining 12% of the total variation. Each of these components reflects asymmetry.

TABLE 13. Palmar Ridge-count Means and Standard Deviations.

	WEST				EAST			
	Males n=83		Females n=65		Males n=42		Females n=38	
	$\overline{X}$	S.D.	$\overline{X}$	S.D.	$\overline{X}$	S.D.	$\overline{X}$	S.D.
Left								
c-d	36.35	6.71	35.03	7.72	36.50	6.25	34.76	7.87
b-c	25.94	5.75	26.00	6.51	25.52	5.62	25.50	5.70
a-b	42.13	6.69	42.62	6.03	41.52	6.38	41.42	6.66
Right								
c-d	38.60	6.32	37.37	6.06	38.05	4.48	36.47	6.30
b-c	26.34	6.06	26.37	5.56	25.38	5.95	26.50	6.28
a-b	39.89	6.70	40.88	5.66	40.67	5.43	40.11	6.09

TABLE 14. Palmar Ridge-count Within Groups Correlation Matrix.

	Left			Right		
	c-d	b-c	a-b	c-d	b-c	a-b
Left						
c-d	1.0					
b-c	0.4468	1.0				
a-b	0.3349	0.2515	1.0			
Right						
c-d	0.6759	0.3917	0.3426	1.0		
b-c	0.5006	0.8237	0.2802	0.3114	1.0	
a-b	0.3149	0.3254	0.7608	0.3711	0.2422	1.0
Grand Means						
	35.737	28.807	42.040	37.794	26.197	40.351
Standard Deviations						
	7.126	5.913	6.420	5.954	5.913	6.068

TABLE 15. Palmar Ridge-count Principal Components.

	Component 1	2	3	4	5	6
Left						
c-d	0.766	-0.163	-0.468	-0.360	-0.183	-0.069
b-c	0.761	-0.457	0.333	0.221	-0.051	-0.221
a-b	0.665	0.630	0.200	-0.184	0.279	-0.099
Right						
c-d	0.716	0.007	-0.594	0.319	0.166	0.067
b-c	0.743	-0.496	0.349	-0.132	0.099	0.229
a-b	0.676	0.619	0.206	0.147	-0.293	0.102
Eigenvalue						
	3.131	1.261	0.887	0.353	0.238	0.131
Variation						
	52.2%	21.0%	14.8%	5.9%	4.0%	2.2%

Component 4 yields opposite loadings for homologous areas. Component 5 contrasts the a-b areas. Component 6 reflects whole hand asymmetry, contrasting the left with the right, especially the b-c count.

Standard scores were then calculated and used in a Multiple Analysis of Variance. Group, sex, and group-sex interaction were the treatments for the model. This procedure was chosen to simultaneously identify the sources of variation which might have been missed by individual univariate tests. The results of this analysis are presented in Table 16.

The full model was not significant for any treatment. No univariate F's were significant for any component. No differences were found between the groups or sexes for any of the six palmar ridge-count components.

The Type IV Sum of Squares provide information about the contribution of each treatment to the model. The partial F on component 3 was significant for sex. Group differences were close to significant on component 5. While not too much should be made of these results, sometimes intelligible trends are noted even though significance is not attained. The component means are presented in Table 17 to clarify further the relationships.

For component 1 (size) and component 5 (asymmetry) the order is by group. The West groups are positive, the East groups are negative. For component 5, the males differ from each other quite markedly.

For component 3 (c-d contrast), and components 4 and 6 (asymmetries) the sexes are ordered. For components 3 and 6 the

TABLE 16. Multivariate Analysis of Variance: Palmar Ridge-count Components.

Full Model

	F	p	df (6,219)
Sex	1.17	0.325	
Group	0.68	0.669	
Sex*Group	0.44	0.855	

F is calculated from Wilks' Lambda

Univariate

Component	F df(3,227)	p	Type IV Sum of Squares
1	0.24	0.869	ns
2	0.28	0.842	ns
3	1.90	0.128	sex .02
4	0.11	0.950	ns
5	1.60	0.188	group .06
6	0.57	0.641	ns

TABLE 17. Palmar Ridge-count Principal Component Means.

Component	WEST Males n=83	WEST Females n=65	EAST Males n=42	EAST Females n=38
1	0.0499	0.0118	-0.0141	-0.1137
2	-0.0575	0.0762	0.0433	-0.0526
3	-0.1331	0.1638	-0.1630	0.1906
4	0.0016	0.0353	0.0143	0.0796
5	0.1436	0.0300	-0.2576	-0.0805
6	-0.0423	0.0113	-0.0934	0.1762

females are positive, the males are negative. For component 4 the females are more positive than the males.

For all components, except component 2, the East males and females deviate farther from the zero mean than do their counterparts in the West. This might be, at least in part, a statistical artifact due to differing sample sizes. The smaller samples might be expected to deviate farther from the mean than the larger samples.

Whether any of these observations is biologically meaningful is open to interpretation. One is free to ponder the significance of ordered non-significance.

<u>Principal Components: Within West Analysis</u>

In order to identify evidence of stress within the West samples, the older individuals were separated from the children born in Australia. The hypothesis was that differences could be found between the groups. Therefore, the West sample was divided into four subsamples: males and females (over age 16 years) born outside of Australia, and males and females born in Australia (all were less than 16 years old). Males and females less than 16 years old and born outside of Australia were excluded from the analysis. The palmar ridge-count variables were analyzed for differences between the samples. The means and standard deviations for each variable are presented in Table 18.

Student's t test adjusted for unequal sample sizes and small n's was used to test the means between the groups. This formula is also presented in Table 18. The left b-c means for the two female samples

TABLE 18. Palmar Ridge-count Means: Within West Analysis.

	Adults		Australian born Children		Adult-Child Difference
	$\bar{X}$	s.d.	$\bar{X}$	s.d.	
Males (58)			Boys (21)		
Left					
c-d	35.53	6.99	38.76	5.84	-3.23
b-c	25.60	6.04	27.52	5.01	-1.92
a-b	42.10	6.42	41.52	7.46	0.58
Right					
c-d	37.93	6.15	39.91	6.99	-1.98
b-c	26.28	5.98	27.48	6.31	-1.20
a-b	39.76	6.31	39.19	7.48	0.57
Female (46)			Girls (17)		
Left					
c-d	34.67	8.31	36.18	6.37	-1.51
b-c	24.91	6.25	28.65	6.92	-3.74*
a-b	42.65	6.19	42.06	5.14	0.59
Right					
c-d	36.94	6.08	38.82	5.77	-1.88
b-c	25.67	5.88	28.35	4.44	-2.68
a-b	40.85	5.88	40.94	5.47	-0.09

*t = 2.05
Males (df 77) $t_{.05} = 2.0$
Females (df 61) $t_{.05} = 2.0$

Formula for Student's t test with unequal sample sizes and small n's.

df $n_1 + n_2 - 2$

$$t_s = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\dfrac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2} \quad \dfrac{n_1 + n_2}{n_1 \times n_2}}}$$

were found to be significantly different at the .05 level.

To investigate further the variation within the West samples, their standard scores were analyzed using the SAS MANOVA subroutine. The treatments were age, sex, and age-sex interaction. These results are presented in Table 19.

The full model was not significant for any treatment. No univariate F's were significant for any component, although the partial F for component 2 was significant (.03) for age. Component 1 approached significance for age, and component 3 for sex.

The means help clarify relationships (Table 20). For components 1, 2, and 6, the age groups are ordered. The children have positive means on the first component, very negative means on the second component. Boys are most negative on the sixth component, with girls weakly negative and adults weakly positive.

For components 3 and 5 the sexes are ordered. On component 3 the males are negative, and the females are positive. For component 5, all are positive, but the males are farther from the mean than the females. No group shows consistent patterning in its relationship to the zero mean.

Regression: Asymmetry vs Age

Regression analysis was performed on three palmar ridge-count asymmetry variables, with age as the dependent variable. Three asymmetry variables were obtained using the right minus left ridge-count for homologous interdigital areas. The variables were analyzed by sex for each age group. The null hypothesis was that no

TABLE 19. Multivariate Analysis of Variance of Palmar Ridge-count Components: Within West Analysis.

Full Model

	F	p	df(6,133)
Sex	0.82	0.557	
Age	1.59	0.156	
Sex*Age	0.32	0.928	

F is calculated from Wilks' Lambda

Univariate

Component	F df(3,141)	p	Type IV Sum of Squares
1	0.94	0.425	ns
2	2.04	0.110	Age .03
3	1.11	0.348	ns
4	0.52	0.672	ns
5	0.26	0.853	ns
6	0.58	0.634	ns

TABLE 20. Palmar Ridge-count Component Means: Within West Analysis.

Component	Boys n=21	Girls n=17	Adult Males n=58	Adult Females n=46
1	0.2482	0.2786	-0.0257	-0.0892
2	-0.3756	-0.2739	-0.0317	0.1951
3	-0.3311	0.1963	-0.0285	0.1248
4	-0.0487	0.2960	-0.0223	-0.0555
5	0.0886	0.0048	0.1825	0.0211
6	-0.2418	-0.0432	0.0242	0.0965

difference exists between the oldest and youngest members of a sample for an asymmetry variable. In this case the correlation would be at, or very near, zero. Asymmetry would be randomly distributed within the sample.

The alternative hypothesis was that a systematic difference would be found. In the samples known to have undergone stress, the older individuals in the West samples would be systematically different from the children who were born in Australia under less stressed conditions.

Table 21 presents the asymmetry variable means. The means were tested using Student's t test. No significant differences were found, so the null hypothesis could not be rejected. No differences in asymmetry variable means could be demonstrated for any age group, stressed or unstressed.

The results of the regression analysis are presented in Table 22. The correlation of age with asymmetry is very low. The r for West males is .014, for females .016. The East males are slightly higher with .032. The East females have a correlation of .132. The associated F's are all non-significant. Bivariate plots of age with each asymmetry variable did not provide further insights. Palmar ridge-count asymmetry is randomly associated with age for all groups.

A Multiple Analysis of Variance was performed to identify any subtle relationships which might have been missed. No differences in asymmetry were identified for sex, age, are sex-age interaction. No univariate F's were significant. No treatments approached significance. No differences exist between the ages or sexes for the three asymmetry variables.

TABLE 21. Right Minus Left Palmar Ridge-count Means.

	West Males n=83		East Males n=42		West Females n=65		East Females n=38	
R-L	$\bar{X}$	s.d.	$\bar{X}$	s.d.	$\bar{X}$	s.d.	$\bar{X}$	s.d.
c-d	2.253	4.85	1.548	4.71	2.338	6.15	1.711	5.72
b-c	0.398	3.59	-0.143	3.29	0.369	3.70	1.000	3.35
a-b	-2.241	4.41	-0.857	4.21	-1.738	4.39	-1.316	4.22

Formula for Student's t test:

$$df = n_1 + n_2 - 2$$

$$t_s = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\dfrac{s_1^2 + s_2^2}{n_1 + n_2}}}$$

Means were tested by sex and group and all were non-significant.

TABLE 22. Regression Analysis: Age*Palm Ridge-count Asymmetry Variables.

	Full Model			
	F	df	p	r
West males n=83	0.38	3,82	0.773	0.014
East males n=42	0.42	3,41	0.740	0.032
West females n=65	0.33	3,64	0.803	0.016
East females n=38	1.72	3,37	0.181	0.132

CHAPTER V

PALMAR RIDGE BREADTH ANALYSIS

As described in Chapter II , six ridge breadth variables were defined: left and right a-b, left and right b-c, and left plus right a-b and b-c. Their means and standard deviations are presented in Table 23 for all individuals older than 16 years.

While ridge-counts do not vary with age, the interdigital distances do increase with growth. Therefore, ridge breadth was calculated for each individual, but one's age determined inclusion in the sample, depending upon the phase of analysis. Growth of the palm was judged to be of adult proportions by age 16 years.

To assess the relationships of age and the six ridge breadth variables in growing children, regressions were calculated with age as the dependent variable. The ages of all individuals 16 years or older were set equal to 16 years. The regression line was then fitted through the mean at 16 years. The slope of this line is not confounded by any adult stress related correlations which might exist, and the positive correlations can be attributed to hand growth.

The results are presented for each group, by sex in Table 24. While the West samples contained many more children than the East samples, this does not account for the higher correlations found in the West analyses. When the correlations were tested, they were found to be significantly different (.05). The adult means are different for the West and East males. This probably affects the fit of the regression slope, causing the correlations to differ. The same is

TABLE 23. Adult Palmar Ridge-counts, a-b and b-c Distance and Ridge Breadth in Microns.

	East Males n=34		West Males n=58		East Females n=32		West Females n=46	
	$\bar{X}$	s.d.	$\bar{X}$	s.d.	$\bar{X}$	s.d.	$\bar{X}$	s.d.
Ridge-count								
Left								
c-d	36.59	5.87	35.53	7.00	35.69	7.73	34.67	8.31
b-c	25.74	4.81	25.60	6.04	26.19	5.32	24.91	6.25
a-b	40.35	5.03	42.10	6.42	41.75	6.86	42.65	6.19
Right								
c-d	38.56	3.27	37.93	6.15	36.56	6.53	36.94	6.08
b-c	25.32	5.31	26.28	5.98	27.25	5.97	25.67	5.88
a-b	39.71	4.91	39.76	6.30	40.53	6.35	40.85	5.88
Distance (mm)								
Left								
b-c	13.59	2.38	13.68	2.99	13.03	2.43	12.60	3.01
a-b	24.06	2.77	24.95	3.75	23.24	2.93	23.39	2.88
Right								
b-c	13.49	2.55	13.74	2.74	13.29	2.41	12.69	3.00
a-b	23.48	2.54	23.52	2.87	22.10	3.13	22.38	2.43
Ridge Breadth								
Left								
b-c	513	60	520	70	483	54	491	60
a-b	584	49	582	63	550	69	539	49
Right								
b-c	516	58	511	74	477	64	477	51
a-b	580	50	584	68	536	58	540	59
Left+Right								
b-c	514	55	514	60	480	53	484	48
a-b	582	47	582	53	542	60	538	44

TABLE 24. Regression Analysis: Ridge Breadth*Age, Full Sample, Adult ages set equal to 16 years.

	Model		
	F	p	r
East Males n=42 (Boys n=8)			
L+R b-c	2.79	0.1028	0.065
L+R a-b	15.21	0.0004	0.276
West Males n=83 (Boys n=25)			
L+R b-c	59.85	0.0001	0.437
L+R a-b	81.22	0.0001	0.513
East Females n=38 (Girls n=6)			
L+R b-c	3.50	0.0694	0.0887
L+R a-b	4.40	0.0429	0.1090
West Females n=65 (Girls n=19)			
L+R b-c	31.02	0.0001	0.3299
L+R a-b	31.94	0.0001	0.3364

true for the females.

The next phase of the analysis was to assess the relationships of age and the ridge breadth variables for those over 16 years old. Regressions were calculated for the six variables by group and sex, with age as the dependent variable. These results are presented in Table 25.

The hypothesis that ridge breadth would differ in the oldest individuals in the stressed groups was tested. To accept this hypothesis, a significant correlation between age and ridge breadth was required. As can be seen from Table 25, this is clearly not the case. Bivariate plots did not reveal any aberrant data points which might be obscuring significant trends. In each case, the scatter of points represented a random association of age and ridge breadth. The very low correlations for the West samples ranged from zero to .046. With twelve males between the ages of 50 and 65 years, and ten females between ages 45 and 68, any existing relationships should not have been obscured by the remainder of the sample. No relationship between age and ridge breadth could be identified for the stressed groups.

While the same random relationships also occur for the East males, the East females have a strong correlation of age with the b-c variables. Bivariate plots reveal that the younger adults (to age 40) are generally associated with smaller ridge breadth dimensions for the b-c interdigital areas. The broader ridge breadth dimensions are associated with the 48 to 55 year olds (n is 6). The two oldest individuals (ages 66 and 70) are at the mean for the summed b-c variables.

TABLE 25. Regression Analysis: Age*Palmar Ridge Breadth, Adult Sample.

	Model		
	F	p	r
East Males n=34			
L+R b-c	0.03	0.7333	0.0009
L+R a-b	0.73	0.3992	0.0223
West Males n=58			
L+R b-c	0.12	0.7333	0.0021
L+R a-b	0.00	0.9738	0.0000
East Females n=32			
L+R b-c	7.18	0.0119	0.1930
L+R a-b	1.63	0.2119	0.0514
West Females n=46			
L+R b-c	1.28	0.2643	0.0282
L+R a-b	0.83	0.3663	0.0186

Because virtually nothing is known about the b-c ridge breadth variable, interpretation of these findings is difficult without a context. Perhaps if further information becomes available for this dimension, the meaning will become apparent.

Table 26 contains the univariate F's for each ridge breadth variable analyzed by sex, group, and sex-group interaction. Sex was the only significant treatment. This finding is not unexpected, as sex chromosomes are known to influence ridge breadth dimensions (Penrose and Loesch, 1967). In addition, racial differences in ridge breadth dimensions between Blacks and Whites have been reported (Jantz and Parham, 1978).

Inspecting the means (Table 23), very minimal differences occur between the groups for the summed ridge breadth dimensions, left plus right b-c and left plus right a-b. However, information is often lost when summary techniques are used. By subtracting the right minus left ridge breadth means, one finds some differences do exist in hand bias (Table 27). The East males have a slight right hand bias for the b-c variable. The other three groups have a left hand bias. Both West groups have a slight right hand bias for the a-b area. The East groups have a slight left hand bias.

Opposition exists between the interdigital areas. When one area is positive (right hand bias), the other is negative (left hand bias). Intuitively, this is reasonable, as a finite amount of space exists on the palm. The East females are an exception, however, with a left bias for both variables.

TABLE 26. Analysis of Variance: Ridge Breadth of Adult Sample.

	Univariate F df(3,169)	p	Type IV Sum of Squares
Left b-c	3.38	0.0195	Sex .001
Left a-b	6.67	0.0003	Sex .0001
Right b-c	4.65	0.0040	Sex .001
Right a-b	7.46	0.0001	Sex .0001
L+R b-c	4.91	0.0028	Sex .001
L+R a-b	9.61	0.0001	Sex .0001

TABLE 27. Components of Ridge Breadth (Right - Left)

	East Males	West Males	East Females	West Females
R-L Ridge Breadth				
b-c	0.003	-0.009	-0.006	-0.014
a-b	-0.004	0.002	-0.014	0.001
R-L Ridge-Count				
b-c	-0.411	0.673	1.063	0.761
a-b	-0.647	-2.344	-1.219	-1.804
R-L Distance				
b-c	-0.096	0.059	0.260	0.082
a-b	-0.584	-1.429	-1.138	-1.009

To investigate further this hand bias in ridge breadth, its components, the right minus left ridge-counts and interdigital distances, were considered (Table 27). Subtracting the ridge-count means for this adult sample reveals an opposition between the variables, with patterning more consistent across the groups. However, the East males have a left bias for both the a-b and b-c ridge-count variables. Right minus left distances show the same patterning of opposition as do the ridge-counts.

In summary, the East males show different patterning than the West males for the ridge breadth components. However, when these components are summed, the means are not different. Finally, it is interesting to note that the standard deviations for all variables are consistently lower for the East males than for the West males (Table 23).

Although the summed ridge breadth means are not very different, the components contributing to these means differ in subtle ways. Recognizing that these differences are not statistically significant for these groups, exploring the relationships with other groups might yield interesting information. The inter-racial level differences may be more significant than these intra-group level differences.

Because the hypothesis of adult age correlation with ridge breadth in the stressed samples could not be accepted, no reason remained to pursue the analysis by adjusting the children's ridge breadth for growth.

Other Group Comparisons of a-b Ridge Breadth

Brief attention was then directed to some limited comparative information available in the literature for a-b ridge breadth. The Armenian data are added to this context (Table 28). The range of variation within the Caucasian samples is great. Student's t tests show the Armenian male means differ significantly from the English sample reported by David and Ajdukiewicz (1978) and the Jewish sample. They also differ significantly from the Yoruba. The female means differ significantly from each of the other groups, although the East females did not differ from the Yoruba. The large standard deviation and small sample size of the East females probably account for this.

TABLE 28. Other Group a-b Ridge Breadth Means.

	Males			Females		
	n	$\overline{X}$	s.d.	n	$\overline{X}$	s.d.
Black African						
Yoruba[a]	119	605	55	52	556	41
Armenians						
East	34	582	47	32	542	60
West	58	582	53	46	538	44
English[b]	60	565	41	60	514	39
Jewish[c]	100	558	45	100	507	74
English[d]	259	541	48	381	493	43

[a] Jantz and Parham (1978)
[b] Penrose and Loesch (1967)
[c] Katznelson and Ashbel (1973)
[d] David and Ajdukiewicz (1978)

CHAPTER VI

CONCLUSIONS

This thesis has explored the dermatoglyphic variability of a stressed and an unstressed sample drawn from an Armenian population. The first hypothesis tested was that the developing dermal ridge system would have been affected by the severe stress known to have occurred. The second hypothesis was that these stressed individuals would show different patterning of dermal ridge relationships, especially in increased directional asymmetry of finger and palmar ridge-counts and variation in ridge breadth on the palms. The intergenerational effect of stress was also explored by comparing the unstressed children born of stressed parents and grandparents.

The second hypothesis was rejected for these data. No evidence of stress, reflected as increased asymmetry or variation in ridge breadth, was discernable using univariate or multivariate analytical techniques. No evidence emerged to support the hypothesis for an intergenerational effect of stress in the dermal ridge system.

In general, significant differences were attributed to the East groups. East males were different for the finger ridge-count means. At this point it is not clear if this is attributable to genetic or environmental causes. The East females were found to have a temporal change in the b-c palmar variable. The relatively small sample size, of course, may have contributed to this finding. Further, this sample may contain peculiarities emphasized by family relationships. Certainly none of the samples may be considered random, but usually a sufficiently large sample size eliminates familial bias.

An alternative hypothesis is tentatively offered for the results of this analysis. Perhaps stress is reflected by a decrease in variability in the West samples. A large portion of the sample consists of adults whose parents suffered stress. The mean for any trait is generally considered to be the most fit. Under stressed conditions those deviating farthest from fitness would be least likely to survive. This adaptive genotype would then be reproduced in the offpring of the survivors. Without these severe environmental constraints, traits would be free to vary more, as exhibited in the East samples.

No increased directional asymmetry was detected in the stressed group as predicted. Indeed, the oldest individuals in the West groups were usually very close to the mean for asymmetry and ridge breadth. Perhaps evidence of stress should be assessed by analyzing the variance differences rather than analysis of mean differences or directional asymmetry. Evidence of stress may exist, but not in the way predicted.

In conclusion, when the entire analysis is considered, the predicted effects of stress in the dermal ridge system have not been detected. Perhaps the predicted effects are incorrect. Until the alternative hypothesis of reduced variability in the West samples is tested, the first hypothesis should not be rejected. Evidence of stress may be recorded in the developing dermal ridge system.

Summary of Conclusions

Finger Ridge-counts: Principal Components

1. The full model of a Multiple Analysis of Variance of the principal components of finger ridge-counts was significant for sex and group.

2. Component 1 (size) and component 2 (radial ulnar contrasts) were heterogeneous for sex and group.

3. East males differ from West males on component 3 (ulnar gradient). Component 6 was significant for sex.

For the principal components of finger ridge-counts differences between the groups could be identified.

Finger Ridge-counts: Asymmetry

1. Ten asymmetry variables: No association of asymmetry and age was found in the regression analyses. No mean differences were identified for group or sex.

2. Two asymmetry variables: The composite asymmetry variables did not enhance group differences.

3. Relationship to other groups: A negative correlation of the two composite asymmetry variables was found for each of the six groups. The strongest negative correlation was found for the stressed groups. The six correlations were not significantly different. The six group variable means were not significantly different for either variable.

For finger ridge-count asymmetry, no evidence of stress was found.

Palmar Ridge-counts

1. No differences exist in the six palmar ridge-count means nor the principal components for the four groups.

2. Australian born girls differ from adult West born females for the left b-c ridge-count mean at the .05 level.

3. No differences can be demonstrated with statistical significance for the six principal components of palmar variation of the West born adults and the children born in Australia.

4. The means of the three asymmetry values of the six ridge-count variables are not different for either group or sex.

5. No significant regression of age and asymmetry values of palmar ridge-counts can be demonstrated for either group or sex.

For palmar ridge-counts, evidence of stress was not discernable.

Palmar Ridge Breadth

1. No relationship between age and ridge breadth could be identified for the stressed groups.

2. The East females have a strong positive correlation of age and b-c ridge breadth.

3. Other group comparisons show a wide range of variation within Caucasian groups for a-b ridge breadth means.

No evidence of stress was found in analysis of ridge breadth.

The following recommendations are offered for future research.

1. The b-c interdigital distances should be recorded. The b-c ridge breadth should be incorporated into the methodology. In this

analysis, b-c ridge breadth was the only source of variation in the entire palmar analysis. The b-c ridge breadth relationship to the a-b ridge breadth dimension should be explored, especially on the inter-racial level.

2. The analysis of palmar ridge breadth asymmetry should yield additional information beyond summing the hands for the a-b and b-c ridge breadth variables.

3. Directional asymmetry was not useful for detecting stress in these data. However, the usefulness of directional asymmetry in developmental models deserves further attention.

4. New statistical approaches should be investigated to test differences in variances rather than mean differences in the Armenian samples.

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