To the Graduate Council:

I am submitting herewith a thesis written by Letitia L. Oliveira entitled "Dermatoglyphics of University of Tennessee Students: Relationships to Height, Weight, Laterality, and Genetic Polymorphisms." I 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:

Accepted for the Council:

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Graduate Studies and Research

DERMATOGLYPHICS OF UNIVERSITY OF TENNESSEE STUDENTS: RELATIONSHIPS TO HEIGHT, WEIGHT, LATERALITY, AND GENETIC POLYMORPHISMS

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ABSTRACT

A study was conducted on 567 female and 389 male Caucasian students at The University of Tennessee, Knoxville, in an attempt to discover the principal components of dermatoglyphic variation and their relationships to the following traits: height, weight, handedness, handclasping, armfolding, color vision, tongue rolling ability, P.T.C. taste reaction, cerumen type, and area of birth within the United States. Principal components analysis was performed on the original dermatoglyphic data, and the first six principal components for fingers and for palms were tested by analysis of variance for correlation with each of the above traits. Subjects of differing height, handedness, handclasping, armfolding, and P.T.C. taste sensitivity showed significantly different dermatoglyphic characteristics.

Evidence was found that environmental disturbances during the period of ridge formation which affect the symmetry of patterns between hands may also affect height, handedness, and armfolding.

A possibility of genetic influence in the expression of handedness and handclasping was indicated by associations between these traits and several dermatoglyphic configurations which have been shown to be inherited characteristics.

Analysis of the data also showed a correlation between P.T.C. tasting ability and radial loops on the fingers of females, with non-tasters tending to have a higher frequency of radial loops than non-tasters.

No evidence was found suggesting relationships between dermatoglyphic characteristics and weight, color vision, tongue rolling ability, cerumen type, or area of birth within the United States.

TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION	1
II.	REVIEW OF THE LITERATURE	5
	Development and Inheritance of Dermal Ridges	5
	Dermatoglyphic Associations with Abnormal Human Variation	8
	Dermatoglyphic Associations with Normal Human Variation	10
III.	MATERIALS AND METHODS	16
	Source of Data	16
	Classification of Dermatoglyphic Data	17
	Statistical Procedures	19
IV.	RESULTS	24
	Principal Components of the Dermatoglyphic Data	24
	Relationships Between Principal Components and Selected Variables	39
V.	DISCUSSION	58
BIBLIOGRAPHY		65
APPENDIX		71
VITA		75

LIST OF TABLES

TABLE		PAGE
1.	Eigenvalues for Finger Components in Females	25
2.	Eigenvalues for Finger Components in Males	26
3.	Component Scores for Radial and Ulnar Loops on Each Digit of Left and Right Hands	30
4.	Eigenvalues for Palm Components in Females	34
5.	Eigenvalues for Palm Components in Males	35
6.	Component Scores for Loops on Palmar Areas of Left and Right Hands	38
7.	Levels of Significant Association from Analysis of Variance	41
8.	Distribution of Subjects by Height	42
9.	Distribution of Subjects by Weight	45
10.	Distribution of Subjects by Handedness and Scores for Significantly Associated Components	46
11.	Distribution of Subjects by Handclasping and Scores for Significantly Associated Components	51
12.	Distribution of Subjects by Armfolding and Scores for Significantly Associated Components	54
13.	Distribution of Subjects by Color Vision, Tongue Rolling Ability, and Cerumen Type	55
14.	Distribution of Subjects by P.T.C. Taste Reaction and Scores for Significantly Associated Components	56
15.	Distribution of Subjects by Area of Birth	57

LIST OF FIGURES

FIGURE PAGE

1. Areas of the Palm Corresponding to Fetal Mounds 7

2. Dermatoglyphic Configurations of Fingers and Palms 19

3. Principal Components of Fingers in Females . . . 28

4. Principal Components of Fingers in Males 29

5. Principal Components of Palms in Females 36

6. Principal Components of Palms in Males 37

7. Mean Component 4 Scores for Fingers in Females by Height. 43

CHAPTER I

INTRODUCTION

This study is concerned with the relationship of dermatoglyphic configurations to height, weight, laterality and genetic polymorphisms in a Caucasian American population. Although extensive research has been done on the dermatoglyphics associated with abnormal human variation, relatively few studies have been conducted on the relationship between dermatoglyphic patterns and non-pathological traits. In the present study finger and palm prints of normal individuals were examined to discern whether or not particular dermatoglyphic characteristics are associated with the common traits of height, weight, laterality expressed in handedness, handclasping, and armfolding, and four genetic polymorphisms--color vision, tongue rolling ability, phenylthiocarbamide (P.T.C.) taste sensitivity and cerumen type.

A sample of 567 female and 389 male Caucasian students was obtained from introductory physical anthropology classes at The University of Tennessee, Knoxville. Finger and palm prints were made using the roller and ink slab technique, and a questionnaire requesting information on sex, height, weight, handedness, and other traits was completed by each subject (see Appendix).

Since the present study was based on a sample of

students, individuals from many areas of the United States are represented in the population. It was therefore felt advisable to test for homogeneity in the sample population by area of birth to see if individuals from different parts of the country would reveal significant differences in dermatoglyphic traits.

Height and weight in adults result from the interaction of many processes, including heredity, growth and development, and environmental influences. Dermatoglyphic peculiarities have been found to exist when these processes are disrupted, i.e., in persons with abnormal growth patterns due to developmental disturbances or chromosomal anomalies. The present study explored the possibility that dermatoglyphic differences exist among normally developed individuals of different height and weight.

Three laterality traits were considered in this study: handedness, handclasping, and armfolding. The criteria used to classify persons as right or left handed have been subject to controversy. Writing hand, which is the most commonly used criterion in laterality studies, was used to determine handedness in this study. When the hands are clasped together with the fingers interlocked, most individuals have a natural tendency to place either the right or the left thumb in a superior position. A person placing the right thumb superiorly is considered a right handclasper, and one whose left thumb is placed in the uppermost position is a left handclasper. Another

lateral trait is the tendency to place one arm superiorly when the arms are folded across the chest. The arm in the superior position determines the classification of an individual as a right or left armfolder.

Handedness, handclasping and armfolding are behavioral traits for which the extent of genetic versus environmental influence is not completely understood. Determining the role of heredity in such a behavioral trait is difficult, since frequency of occurrence within a population does not necessarily prove its inheritance. "The most convincing evidence of a genetic basis for a behavioral trait is to establish an association between it and a highly heritable physical variation which develops during fetal life, and which is not altered by postnatal circumstances." (Rife 1955:170). As a trait which has heritable characteristics, is extremely variable, and is subject to environmental influence only during the first three or four fetal months, ridged skin is a useful medium for investigating the heritability of lateral traits. This study attempted to discover associations between dermatoglyphics and handedness, handclasping and armfolding which would indicate the involvement of genetic factors in the manifestation of these three behavioral traits.

Another aspect of normal human variation is the expression of genetic polymorphisms. Four polymorphisms were considered in this study: color vision, tongue rolling

ability, P.T.C. taste reaction and cerumen type. All four polymorphisms are controlled by dominant/recessive alleles. Color blindness is known to be a sex-linked recessive trait, and ability to curl or roll the tongue is controlled by a dominant allele. Taste sensitivity to the chemical phenylthiocarbamide is determined by a completely dominant gene, with the inability to taste P.T.C. expressed by the homozygous recessive genotype (Burns 1972). Human cerumen (earwax) exists in two types, wet/sticky or dry/flaky, with wet dominant over dry (Matsunaga 1962).

Since the genetic mechanisms controlling these polymorphisms are known, investigation of the relationship between the polymorphisms and dermatoglyphics could yield two types of information. First, for two traits known to be under genetic control, significant association between them would suggest possible linkage between the genes involved or a pleiotropic effect acting upon both traits. Secondly, when the relationship between a hereditary trait and a trait of unknown genetic basis is concerned, a statistical association between the traits could indicate possible genetic involvement in the expression of the latter trait, in which case family studies would be needed to prove or disprove its heritability. Therefore, by investigating the relationships between dermatoglyphic configurations and polymorphisms, the present study sought to illuminate the genetic processes involved in dermatoglyphic expression.

CHAPTER II

REVIEW OF THE LITERATURE

During the last fifty years there has been an increasing awareness of the usefulness of dermatoglyphics as a means of understanding human variation. Three areas of concern will be considered in the present review of the literature: Section I consists of a brief summary of information on the development and inheritance of dermal ridges; Section II discusses some of the research done in correlating ridge configurations with pathological disorders; and Section III presents studies dealing with the associations between dermatoglyphics and several traits characteristic of normal human variation.

I. DEVELOPMENT AND INHERITANCE OF DERMAL RIDGES

Differentiation of dermal ridges occurs in the fetus during the third and fourth pre-natal months. The initial stage of differentiation begins when the hand is about 3.5 mm. long and is completed when it is about 15.6 mm. long. After this time no change in pattern seems to occur during intrauterine growth. During the seventh pre-natal month the dermal papillae develop, and the epidermal ridges are complete in every respect (Holt 1968).

Galton (1892) first proved that dermatoglyphic patterns

persist unchanged throughout an individual's life. The only post-natal changes in ridges are those of size, as the ridges keep pace with the growth of hands and feet. Environment, therefore, can influence development of ridges only in the uterus during the period of ridge formation. Although deep injuries to the skin may cause scars which result in permanent distortion of the ridges, these are easily recognized (Holt 1968).

The determination of ridge configurations is due partly to heredity and partly to accidental or environmental influences producing stress and tension in growth during fetal life. The variable alignment of ridges is caused by differential growth, which produces characteristic irregularities in the form of hands and feet. Ridge configurations occur on the sites of the volar pads, which in the fetus are areas of differential growth. Early in the fourth pre-natal month these pads begin to subside. A pattern results if subsidence is incomplete before ridge formation begins. Patterns, therefore, occur in specific areas of the palm and sole, as shown in Figure 1.

From our present state of knowledge about the inheritance of dermal ridges, it appears that environmental factors affect configurations on fingers to a lesser extent than those on palms. This may be due to the fact that ridges appear first on the balls of fingers and later on the palms and soles (Holt 1968). Holt (1952) established the multi-

factorial inheritance of finger ridge counts as being due to polygenes with additive effect. The number of loci and alleles involved is unknown at present. Once the genetics had been worked out by Holt, it became increasingly clear that dermatoglyphic studies could help to illuminate the ongoing processes of human evolution.

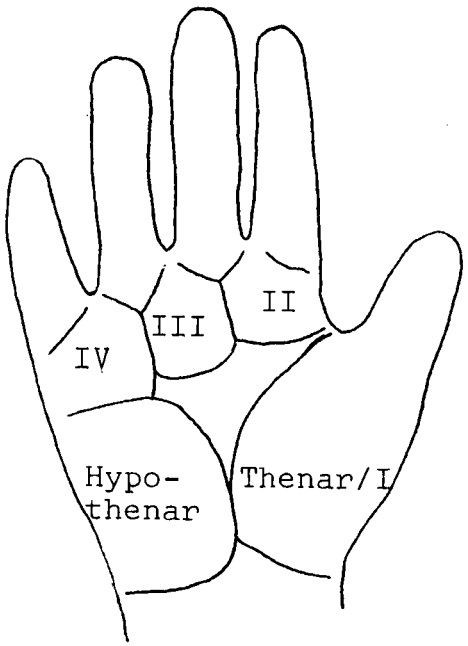


Figure 1. Areas of the Palm Corresponding to Fetal Mounds

II. DERMATOGLYPHIC ASSOCIATIONS WITH ABNORMAL HUMAN VARIATION

Much research has been done in correlating dermatoglyphic traits with chromosomal aberrations and developmental anomalies. Arrangements of ridges are affected by developmental disturbances during the period of ridge formation, and since by the fourth pre-natal month ridge patterns are in their permanent form, anomalies are preserved. Ridge patterns thus reveal irregularities in the growth process during the period of ridge formation. For example, use of thalilomide by pregnant mothers has caused dermatoglyphic distortions (Holt 1968). Cummins and Midlo (1943) pointed out that abnormal ridge arrangements are associated with all malformations of the hands and feet.

Achs et al. (1966) studied unusual dermatoglyphics associated with major congenital malformations. Infants were examined within twenty-four hours after birth and were classified as either normal or abnormal on the basis of physical examination alone. A major congenital malformation was defined as

> a life-threatening condition such as imperforate anus or omphalocele, a major cosmetic problem such as cleft palate or absent auricles, a condition that might shorten survival such as congenital heart disease or meningomyelocele or a condition that impairs normal functioning such as congenital dislocation of the hips (Achs 1966:1275).

Children with obvious chromosomal anomalies were excluded

from the study. The authors found that children with major congenital malformations had a significant incidence of unusual dermatoglyphic traits: simian lines, bilateral distal axial triradii, single flexion creases and radial loops on other than the second finger.

Inherited abnormalities such as anonychia (absence) of nails), nail patella syndrome (abnormal nail formation), and zygodactily (webbing between fingers or toes) show unusual dermatoglyphic traits (Holt 1968). For example, in anonychia, which is due to a dominant autosomal gene, where the nail is usually completely absent or diminished on fingers and toes, the ridges extend over the area usually covered by the nail (Penrose 1965a). Skeletal malformations such as polydactyly (extra digits), syndactyly (fusion of the bones of digits), brachydactyly (shortened phalanges) and ectrodactyly (reduction in number and fusion of digits) also show abnormal dermatoglyphic characteristics (Holt 1968).

David (1973) reported congenital malformations of the dermatoglyphics themselves, including ridge aplasia (absence of ridges), ridge hypolasia (reduced height of ridges), ridge dissociation (broken and disorganized ridges) and ridges-off-the-end (ridges running vertically off the fingertip or palm). Except for the ridges-off-the-end syndrome, which appeared to be purely dermatoglyphic, these anomalies were associated with one or more other aberrations including chromosomal abnormalities, congenital heart disease,

and hairlip.

Distortion in ridges associated with chromosomal aberrations has been extensively studied. Characteristic peculiarities in ridge configuration have been demonstrated for at least three autosomal trisomy syndromes: mongolism (trisomy 21), trisomy 13 (14 or 15), and trisomy 17 (or 18) (Holt 1968, Penrose 1963, Dallapiccola and Capra 1973). It has also been shown that normal bilateral symmetry between hands is disturbed by chromosome abnormalities (Polani and Polani 1969).

A review of all the literature concerning associations between dermatoglyphic configurations and pathologies is beyond the scope of this study. However, the research previously cited should be sufficient to indicate the wide range of abnormal human variability which can be expressed in ridge patterns.

II. DERMATOGLYPHIC ASSOCIATIONS WITH NORMAL HUMAN VARIATION

Examination of dermatoglyphic variation has not been confined to pathological studies. Since the early 1930's attempts have been made to find associations between ridged skin patterns and normal variation in human populations.

Height and Weight

This author is not aware of any research which has

been done on the association between dermatoglyphic traits and normal ranges of height and weight.

Handedness, Handclasping and Armfolding

Most of the studies of dermatoglyphics and normal human variation have been related to the association between dermatoglyphic traits and handedness. Newman (1930) found a strong tendency for the left hander of a twin pair to show a mirror-image relation with the right hander of the pair with respect to palmar configurations, indicating that a reversal in palm configurations is usually correlated with a reversal in functional dominance. He also found that left handers are less asymmetrical in dermatoglyphic configurations than right handers (Newman 1934).

A difference in pattern frequency on right and left palms was noted by Cummins et al. (1931), with the right hand higher in frequency of patterns in the hypothenar, second and third interdigital areas; left hands showed a higher frequency in thenar/I and interdigital area IV. A follow-up study by Leche (1933) on the same group showed that certain dermatoglyphic traits were reversed with the functional dominance of the left hand; she found that while bimanual variations remain, left handers show an accentuation of dextral tendencies, i.e., an increase of patterns in the hypothenar, second, and third interdigital areas.

The first study of gene linkage relations of

dermatoglyphic traits was done by Rife (1941) on the members of 26 families. Rife found evidence for autosomal linkage between factors responsible for handedness and the formation of patterns in the fourth interdigital area. Further studies showed that differences between pattern frequencies of left handers and right handers are consistent but slight as compared with the bimanual differences occurring within individuals (Cromwell and Rife 1942). Rife's work also corroborated Newman's observation of less bilateral asymmetry in left handers than in right handers Rife (1955). A later study by Rife and Kloepfer (1943) on sibships from ten families showed no indication of linkage between handedness and hand patterns.

The author was unable to find any studies made on the relationship of dermatoglyphics and the handclasping or armfolding traits.

Color Vision, Tongue Rolling Ability, P.T.C. Taste Reaction, and Cerumen Type

Mohr (1954) conducted tests to discover the relationship of finger ridge count to P.T.C. tasting ability in the hope of discovering genetic linkage between the two hereditary traits. However, he found no evidence of linkage between finger ridge count and P.T.C. tasting. Veale also conducted linkage tests between total finger ridge count and P.T.C. taste sensitivity, with the same results (Veale 1965).

Pons (1956) studied 175 sibling pairs from Barcelona, Spain, for linkage between P.T.C. tasting and five palmar configurations (hypothenar, thenar, second, third, and fourth interdigital areas). The sib pairs were grouped into four classes (like in both traits, like in P.T.C. tasting and unlike in dermatoglyphic traits, unlike in P.T.C. tasting and like in dermatoglyphic traits, and unlike in both traits) for each of the five palmar areas. No significant statistical associations were revealed, and Pons concluded that there was no genetical association between the traits.

No studies were found concerning the relationship between dermatoglyphic traits and color vision, tongue rolling ability, or cerumen type.

Area of Birth

The author is not aware of any research dealing with the association of dermatoglyphic configurations and area of birth within the United States.

Related Research

Association between dermatoglyphics and blood groups has been studied by several investigators. Mohr (1954) found some indication of linkage between the Lewis blood factor and finger ridge count. However, Mohr did not find any evidence for linkage between finger ridge count and sex, or the ABO, MN, Rh, Lutheran, P and Duffy blood groups.

Neither was any indication of linkage between palmar patterns and the ABO and MN blood groups found by Rife and Kloepfer (1943). Veale (1965) conducted linkage tests between total finger ridge count and the following markers: ABO, MNS, P, Rh, Lu, K, Le, and Fy blood groups, secretor factor (ABH), haptoglobins, and familial intestinal polyposis. No evidence of close linkage was found.

Rife (1971) studied the association between palm patterns and pigmentation in a Cherokee Indian population of mixed Indian-White origin. Estimates of skin pigmentation were made and percentages of Cherokee ancestry were obtained. Rife found that frequencies of patterns in three palmar areas showed significant associations with degrees of pigmentation, with the highest association occurring between light pigmentation and accessory triradii in distal interdigital areas (II, III, and IV). He suggested that linkage could result in such an association.

> The incidence of accessory triradii in distal palmar areas is significantly lower among all American Indian tribes that have been investigated among populations of European origin. Under these circumstances the observed association between lightness of pigmentation and incidence of accessory triradii in distal palmar areas would be expected in populations of mixed Indian-White origin. The degree of association should diminish in successive generations until approximate equilibrium is attained (Rife 1971:74).

Rife does acknowledge that the observed differences in degree of association are of insufficient magnitude to be

sure they are not due to chance fluctuations. Therefore, he concludes that the data neither rule out nor confirm linkage between genes responsible for dark pigmentation in American Indians and accessory triradii in distal areas of the palm.

CHAPTER III

MATERIALS AND METHODS

The data and procedures employed in the present study will be discussed in three sections. Section I discusses the sample population and kinds of data obtained, Section II presents the method used to classify dermatoglyphic traits, and Section III consists of the statistical procedures used in this study.

I. SOURCE OF DATA

The present study was based on finger and palm prints of 567 female and 389 male Caucasian University of Tennessee, Knoxville, students who were enrolled in introductory physical anthropology classes in 1972-75. Rolled prints were obtained using printer's ink. At the same time the prints were made, each student filled out a Human Variation Questionnaire (see Appendix) containing information such as sex, race, height, handedness, and tongue rolling ability. P.T.C. tasting sensitivity was tested using P.T.C. saturated paper prepared by the Department of Anthropology at The University of Tennessee. All other information was based on the students' knowledge about themselves. Since the questionnaire was self-administered it is possible that some of the information provided was inaccurate. However, there should not be

enough errors to significantly affect the results of this study. The sample was limited to American students, non-twins, whose parents were both born within the continental United States. Individuals who stated no lateral preference for writing hand, handclasping or armfolding were excluded from the study.

The following information from the Human Variation Questionnaire was recorded on computer cards for each individual: height, weight, writing hand, handclasping, armfolding, color vision, tongue rolling ability, cerumen type, P.T.C. reaction, and number of siblings. In addition, the following information was recorded: area of birth (Tennessee, Southeastern United States, Other) and state of birth of the student and both parents. For students from Tennessee the following additional data was recorded: county of birth, number of parents born in Tennessee, and number of parents born in the same county in which the student was born.

II. CLASSIFICATION OF DERMATOGLYPHIC DATA

One of the problems inherent in past dermatoglyphic studies has been inconsistency in the classification of pattern types. Most of the data reported has been analyzed by Galton's (1892) system of arches, loops and whorls as elaborated by Cummins and Midlo (1943). However, Penrose and Loesch (1970) worked out a system of classification of fingers and palms based on topological principles. The

topological classification describes all loops and triradii. Penrose defines a triradius as "the center of the delta-shaped, or deltoid, junction of three regions each containing curved streams of approximately parallel ridges," and a loop occurs when "a parallel field of lines turns through two right angles" (1968:4). Each loop has an associated triradius. A whorl is counted as two loops, and it has two associated triradii. On a normal palm there will be four more triradii than there are loops (Penrose 1965b, Penrose and Loesch 1970). Patterns on fingers are designated as radial or ulnar loops. A radial loop opens toward the radial side of the palm, an ulnar loop opens to the ulnar side of the palm, and a whorl is considered as one radial and one ulnar loop (Figure 2).

In the present study finger and palm prints were analyzed according to the system of Penrose and Loesch. The ten fingers were scored for the number of radial and/or ulnar loops. A loop on the palm was specified according to the area in which it occurred and the direction of its core. Loops are classified as peripheral, i.e., I, II, III, IV, and H, when their cores point away from the center of the palm. An $\hat{H}$ loop is on the hypothenar area with its core pointed toward the center of the palm. An H^r loop is on the hypothenar area with its direction and exit toward the radial side of the wrist. An I^r loop is a peripheral loop on the thenar/I area with its exit on the radial thenar border

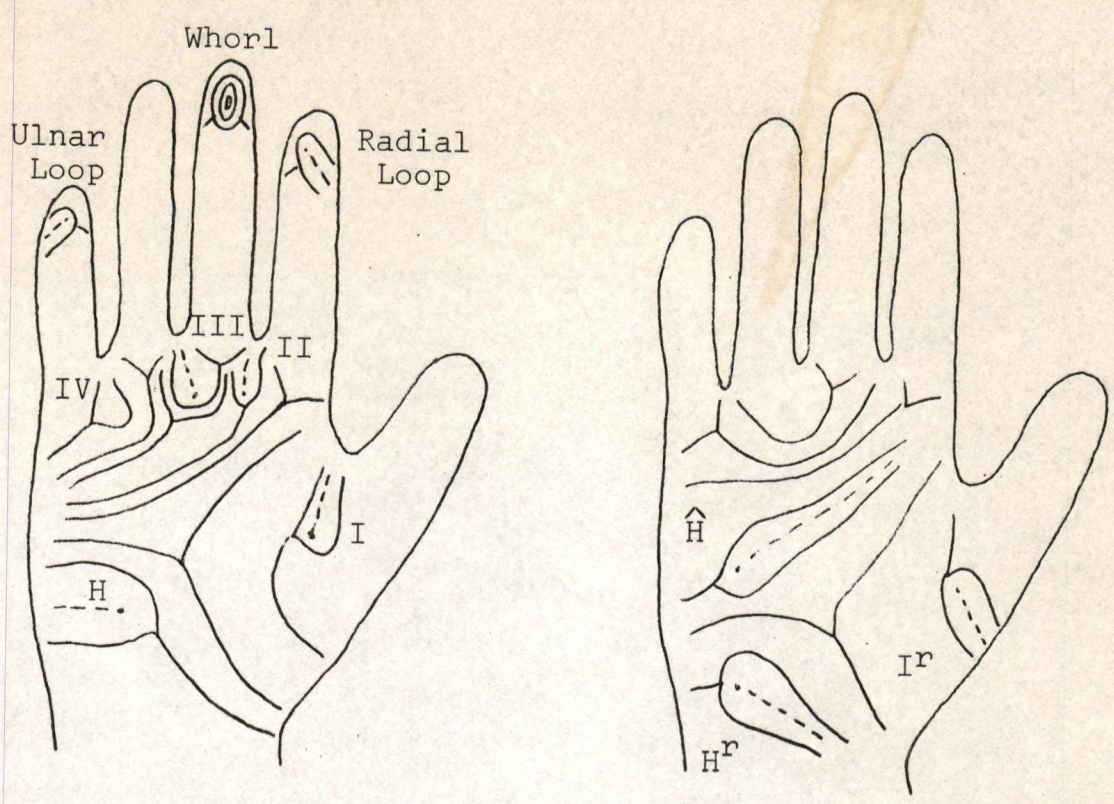


Figure 2. Dermatoglyphic Configurations of Fingers and Palms

(Penrose and Loesch 1970). The number of loops in each area was recorded for each palm.

III. STATISTICAL PROCEDURES

Since the time of Galton (1892), who observed a close correlation between the patterns on the fingers of an individual, correlation between dermal traits on the hands of an individual have been noted. Bonnevie (1924), Holt (1951) and Mavalwala (1962) using finger ridge count showed that ridge counts on homologous fingers and adjacent fingers are more highly correlated than those on fingers further apart. Other investigators have found correlations between finger and

palmar patterns. Mukherjee (1966) showed a negative correlation between the number of triradii on palms and fingers. Research by Loesch (1971) revealed significant associations between patterns on the fourth finger and palmar configurations, as well as a correlation in females between the loop on interdigital area II and the third and fifth fingers. However, most dermatoglyphic studies have neglected this interdependence of dermatoglyphic traits, using simple pattern frequencies or ridge counts as input data.

Principal components analysis provides a way to reduce the 20 variables on the 10 fingers (radial and ulnar loops) and the 16 variables on the palms (I, I^r, II, III, IV, H, $\hat{H}$, H^r for each palm) to two new sets of composite variables that are orthogonal (uncorrelated) to each other--one set for fingers and the other for palms. Principal components analysis makes no particular assumption about the underlying structure of the variables; it simply asks what particular combination of variables would account for the most variance in the data as a whole. The first principal component is the best summary of linear relationships exhibited in the data. The second component is the second best linear combination of variables; i.e., it accounts for the most residual variance after the effect of the first component is removed from the data. Subsequent components are extracted until all the variance in the data is explained (Nie et al..1975).

In principal components analysis a linear transformation is applied to the p observed variates $x_1, x_2, \ldots, x_p$, to produce a new set of uncorrelated and standardized variates $z_1, z_2, \ldots, z_p$. The principal components model may be expressed by the equation

$$x_i = \sum_{r=1}^{p} w_{ir} z_r \quad (i,r = 1,2, \ldots, p)$$

where z_r stands for the rth component and w_{ir} is the weight of the rth component in the ith variate. In a principal components analysis the total variance of the variates is accounted for when all p components are found (Lawley and Maxwell 1963).

Principal components analysis was performed on the finger and palm print data using the FACTOR subroutine of the Statistical Package for the Social Sciences (SPSS) Version 6, which was designed by N. H. Nie, C. H. Hull, J. G. Jenkins, and K. Steinbrenner at the University of Chicago and D. H. Brent at the University of Alberta (1975). The I.B.M. 360/65 computer at the University of Tennessee, Knoxville, was used to process the data. In the present analysis the initial unrotated component matrix was used, and communalities, eigenvalues, and proportion of total and common variance were obtained. Component scores for each individual in the sample were output and merged with data

from the Human Variation Questionnaire for the same individual. Principal components analysis and all subsequent analyses were done separately for palms and for fingers.

Using an option of subprogram BREAKDOWN of SPSS, a one-way analysis of variance was performed to test for significant association between the uncorrelated dermatoglyphic data (principal components) and the variables obtained from the Human Variation Questionnaire (e.g., height, weight, handedness). In analysis of variance all of the data for each test are treated at once, and a general hypothesis of no difference among the means of the various groups is tested. An F test shows whether the probability of heterogenity between and among groups is due to random sampling. If the F score is not significant, the null hypothesis of no difference between the two group variances stands (Downie and Heath 1970). However, if an F score is significant, for example, at the 0.05 level, the probability of such an association occurring by chance is less than 5%.

Because sex differences in ridge configurations exist, all analyses were done separately for females and males. For example, in an English sample, Holt (1968) noted that dermatoglyphic differences between the sexes include ridge breadth and frequencies of pattern types in the various dermatoglyphic areas. The ridges in males are generally wider. Also, on fingers females tend to have a higher frequency of arches, fewer radial loops and fewer

whorls than males. On palms, fourth interdigital and hypothenar patterns are more frequent in females, whereas in males thenar/first, second, and third interdigital patterns are more frequent.

CHAPTER IV

RESULTS

Results of the present study will be discussed in two sections. Data from the principal components analysis of dermatoglyphic configurations will be presented in the first section. The second section discusses the results obtained from testing for significant association between the principal components and variables selected from the Human Variation Questionnaire.

I. PRINCIPAL COMPONENTS OF THE DERMATOGLYPHIC DATA

Analysis of Fingers

Principal components analysis of finger configurations was performed separately for females and males. The eigenvalues (roots) corresponding to each of the 20 components are presented in Table 1 (females) and Table 2 (males), along with the percent of variance accounted for by each component and the cumulative percent of total variance accounted for by the combined components.

It has been noted that when the eigenvalues drop below unity (1.00) the variance accounted for by subsequent components is less than that accounted for by a single original variable (Benfer 1975, Goodman 1972). Principal components analysis of finger dermatoglyphics revealed seven

Table 1. Eigenvalues for Finger Components in Females

Component	Eigenvalue	% of Variance	Cumulative %
1	4.780	23.9	23.9
2	2.608	13.0	36.9
3	1.579	7.9	44.8
4	1.303	6.5	51.3
5	1.201	6.0	57.4
6	1.102	5.5	62.9
7	1.023	5.1	68.0
8	0.955	4.8	72.8
9	0.890	4.4	77.2
10	0.670	3.3	80.6
11	0.602	3.0	83.6
12	0.481	2.4	86.0
13	0.436	2.2	88.1
14	0.432	2.2	90.3
15	0.385	1.9	92.2
16	0.349	1.7	94.0
17	0.338	1.7	95.7
18	0.313	1.6	97.2
19	0.293	1.5	98.7
20	0.261	1.3	100.0

Table 2. Eigenvalues for Finger Components in Males

Component	Eigenvalue	% of Variance	Cumulative %
1	3.935	19.7	19.7
2	3.123	15.6	35.3
3	1.781	8.9	44.2
4	1.330	6.7	50.8
5	1.198	6.0	56.8
6	1.160	5.8	62.6
7	0.948	4.7	67.4
8	0.931	4.7	72.0
9	0.739	3.7	75.7
10	0.715	3.6	79.3
11	0.589	2.9	82.2
12	0.537	2.7	84.9
13	0.518	2.6	87.5
14	0.464	2.3	89.8
15	0.435	2.2	92.0
16	0.400	2.0	94.0
17	0.369	1.8	95.9
18	0.315	1.6	97.4
19	0.259	1.3	98.7
20	0.253	1.3	100.0

components with eigenvalues greater than 1.00 for females and six for males. The first six components account for approximately 63% of the total variance for both females and males. These six components were used in tests for association and will be presented in detail below.

Figure 3 graphically represents the weightings for the first six principal components of finger dermatoglyphics for the female subsample, and Figure 4 shows the first six components for the male subsample. The component scores, or weightings, are also presented in tabular form in Table 3. The first three principal components are similar for females and males. All weightings of Component 1 are positive and reflect the overall magnitude of each variable, i.e., pattern intensity. Component 2, an ulnar loop factor, contrasts radial and ulnar sides of the fingers, the radial side having a negative weighting and the ulnar side a generally positive weighting. Component 3 strongly contrasts the radial and ulnar sides of the second digit.

Components 4, 5, and 6 differ between males and females. In females, Components 4 and 6 suggest bilateral asymmetry between digits II and III on the left and right hands. Component 5 in females appears to reflect a gradient from ulnar to radial sides of the hand. In males, Component 4 contrasts high positive weightings for the ulnar side of digits III and IV and the radial side of digit II against negative weightings for digits I (ulnar side), III (radial)

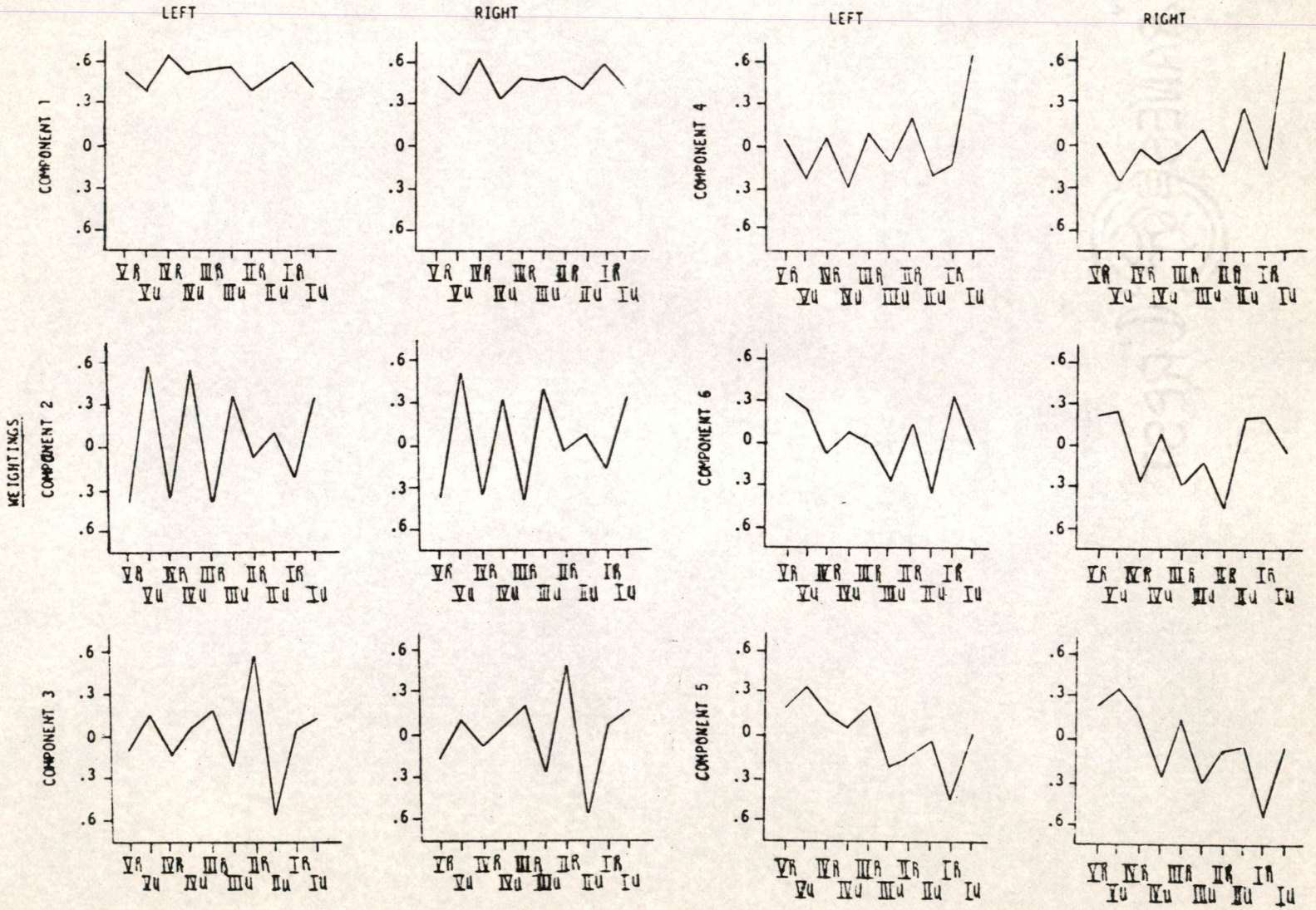


Figure 3. Principal Components of Fingers in Females

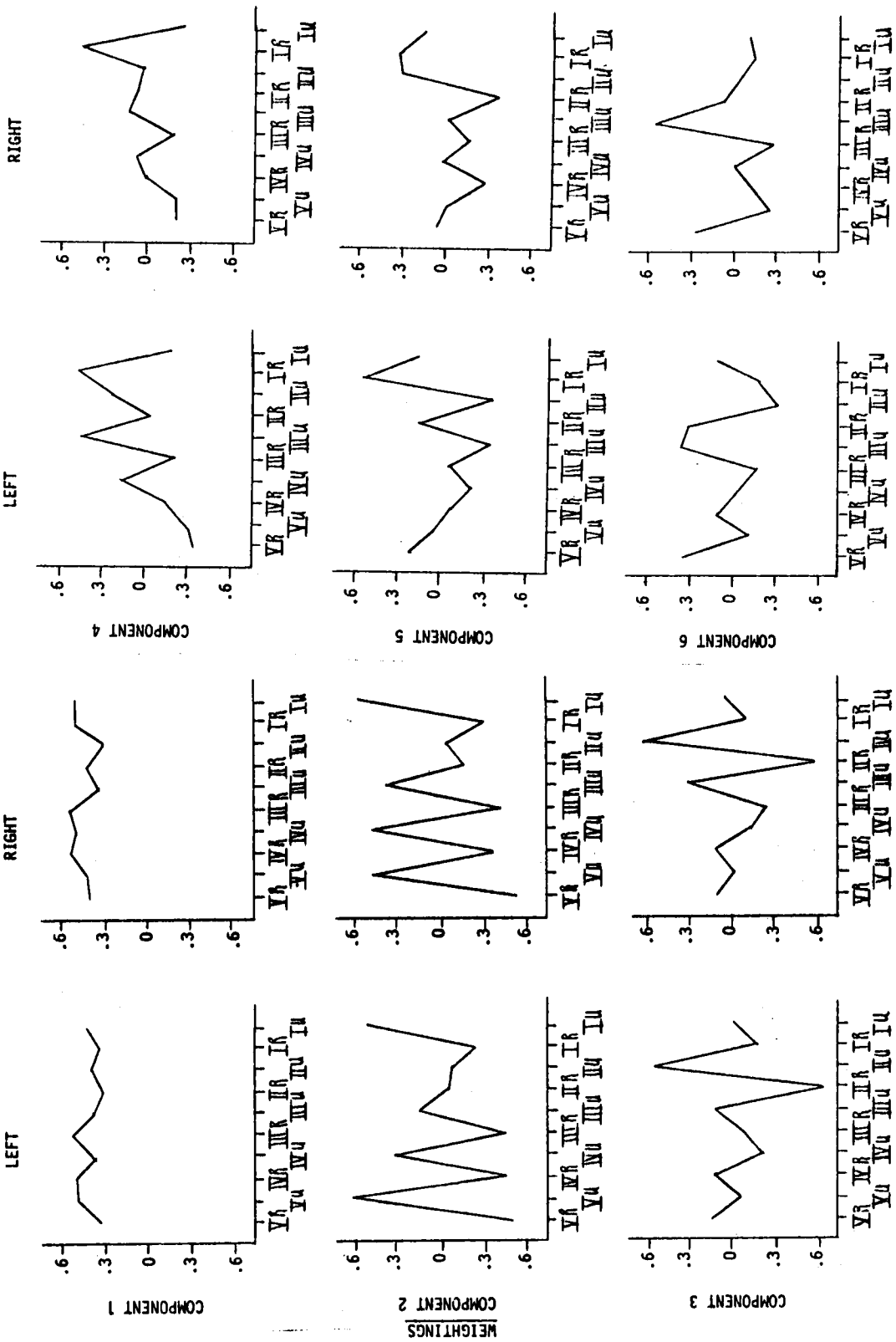


Figure 4. Principal Components of Fingers in Males

Table 3. Component Scores for Radial and Ulnar Loops on Each Digit of Left and Right Hands.

	FEMALES						MALES					
	1	2	3	4	5	6	1	2	3	4	5	6
Left:												
VR	.52	-.40	-.12	.06	.20	.33	.35	-.47	.16	-.33	.21	.35
VU	.41	.59	.15	-.23	.34	.24	.50	.63	-.03	-.31	.07	-.12
IVR	.63	-.36	-.14	.06	.18	-.07	.51	-.48	.14	-.15	-.07	.12
IVU	.51	.53	.07	-.31	.09	.09	.40	.36	-.21	.27	-.19	-.04
IIIR	.52	-.39	.16	.11	.23	-.00	.52	-.41	-.06	-.22	-.09	-.17
IIIU	.52	.38	-.18	-.14	-.20	-.28	.41	.25	.11	.45	-.35	.38
IIR	.41	-.08	.59	.17	-.15	.15	.33	-.06	-.65	-.03	.17	.32
IIU	.48	.09	-.57	-.20	-.04	-.35	.41	-.09	.55	.27	-.33	-.31
IR	.53	-.28	.03	-.14	-.46	.35	.35	-.22	-.19	.47	.59	-.17
IU	.42	.37	.13	.61	.04	-.07	.45	.52	.01	-.17	.16	.11
Right:												
VR	.50	-.42	-.19	.01	.25	.22	.43	-.52	.12	-.20	.08	.29
VU	.40	.53	.12	-.25	.39	.23	.44	.47	.00	-.20	.01	-.26
IVR	.61	-.35	-.08	-.05	.21	-.27	.52	-.39	.12	.00	-.27	-.14
IVU	.33	.32	.08	-.14	-.26	.10	.48	.47	-.12	.09	.03	-.02
IIIR	.50	-.36	.21	-.07	.15	-.29	.52	-.44	-.22	-.20	-.17	-.30
IIIU	.49	.41	-.23	.11	-.24	-.12	.39	.33	.30	.14	-.04	.54
IIR	.49	-.08	.49	-.18	-.10	-.45	.43	-.16	-.58	.10	-.36	.06
IIU	.41	.08	-.59	.26	-.07	.21	.35	-.05	.63	.06	.30	-.03
IR	.58	-.24	.09	-.15	-.51	.20	.49	-.29	-.09	.47	.34	-.16
IU	.41	.36	.12	.65	-.02	-.05	.50	.55	.04	-.27	.15	-.13

R = Radial Loop U = Ulnar Loop

side) and V. Component 5 in males appears to be similar to Component 6 in females; i.e., it shows asymmetry between hands. However, asymmetry in males appears in digit IV as well as in digits II and III. Component 6 in males is difficult to interpret. The left hand weightings strongly contrast radial and ulnar sides of digits II, III and V; right hand weightings contrast radial and ulnar sides of digits III and V.

Similar components were found by Roberts and Coope (1975), who studied the principal components of finger ridge counts in an English sample of about 800 females and 800 males, broken into subsamples consisting of urban and rural populations for each sex. They found four components for both urban and rural males with eigenvalues greater than 1.00, accounting for 63-67% of the total variance for males; five components greater than 1.00 were found for both female subsamples, accounting for 68-72% of the total variance for females. Their first component was equated with the general size factor, the second component with the differentiation between radial and ulnar counts on the fingers, the third component with the contrast between radial and ulnar sides of the hand, the fourth component with radial and ulnar sides of the second digit, and the fifth component with the contrast between mesial and lateral digits. The first four components extracted in their analysis also appeared in the present study. It should be noted, however, that the five

components extracted by Roberts and Coope were similar in both male and female subsamples, whereas in the present study only the first three components were similar for both sexes.

Knussman (1967) carried out a study using factor analysis on ridge counts and pattern types. He found factors generally equivalent to the first, third and fifth components of Roberts and Coope, and Components 1 and 3 of the present study. However, by using only unilateral ridge count Knussman disregarded the radial/ulnar aspect of fingers and thus lost some information.

It should be noted that Knussman and Roberts and Coope used finger ridge count in their research, whereas the present analysis was based on the scoring of radial and ulnar loops. A positive correlation between pattern intensity and ridge count has been observed by various investigators (Holt 1961, Parsons 1964). Thus, some similarity can be expected between principal components for ridge counts and those for the number of loops. Different components can also be expected since two different measurements, although correlated, are being considered: ridge count is a measure of pattern size, and frequency of loops is a measure of pattern intensity.

Analysis of Palms

Principal components analysis of palmar configurations

was also performed separately for females and males. The eigenvalues for each of the 16 components are presented in Table 4 (females) and Table 5 (males). Six principal components with eigenvalues greater than 1.00 were found for both females and males, accounting for 65.6% of the total variance in females and 64.2% in males. Figure 5 represents the weightings for the first six principal components of palmar dermatoglyphics in the female subsample, and Figure 6 shows the first six components for the male subsample. Component scores are also tabulated in Table 6.

Components 1 and 3 are similar for both sexes; however, the other four components are different for females and males. Component 1 in both sexes appears to reflect the overall magnitude of the variables; interdigital areas III and IV, where patterns occur most often, are strongly contrasted with each other, which indicates that patterns tend to occur in either one or the other area, but not in both simultaneously. Component 3 in both sexes shows a negative weighting for interdigital areas II and III, with positive weightings in other areas.

In females Component 2 contrasts thenar patterns with other areas of the palm. Component 4 sharply contrasts interdigital area II with III; it also contrasts H and H^r with $\hat{H}$. Component 5 shows strong positive weightings for interdigital area II and $\hat{H}$, with other weightings generally close to zero. Component 6 sharply contrasts H^r with other

Table 4. Eigenvalues for Palm Components in Females

Component	Eigenvalue	% of Variance	Cumulative %
1	2.540	15.9	15.9
2	2.270	14.2	30.1
3	1.641	10.3	40.3
4	1.580	9.9	50.2
5	1.390	8.7	58.9
6	1.068	6.7	65.6
7	0.889	5.6	71.1
8	0.830	5.2	76.3
9	0.730	4.6	80.9
10	0.635	4.0	84.8
11	0.550	3.4	88.3
12	0.472	2.9	91.2
13	0.467	2.9	94.1
14	0.432	2.7	96.8
15	0.339	2.1	99.0
16	0.168	1.0	100.0

Table 5. Eigenvalues for Palm Components in Males

Component	Eigenvalue	% of Variance	Cumulative %
1	2.518	15.7	15.7
2	2.256	14.1	29.8
3	1.592	10.0	39.8
4	1.421	8.9	48.7
5	1.329	8.3	57.0
6	1.152	7.2	64.2
7	0.970	6.1	70.2
8	0.839	5.2	75.5
9	0.818	5.1	80.6
10	0.714	4.5	85.1
11	0.561	3.5	88.6
12	0.514	3.2	91.8
13	0.466	2.9	94.7
14	0.407	2.5	97.2
15	0.275	1.7	99.0
16	0.167	1.0	100.0

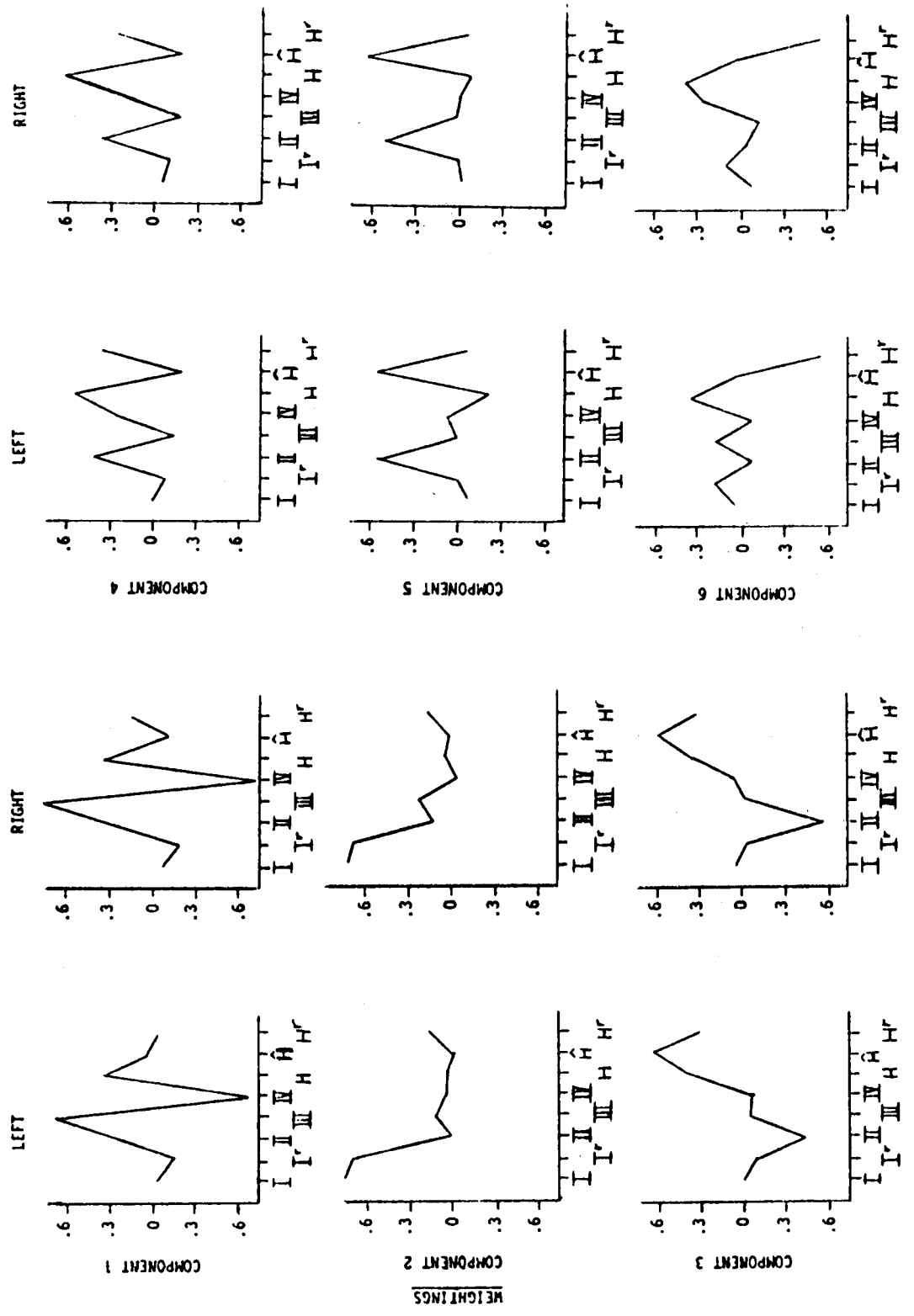


Figure 5. Principal Components of Palms in Females

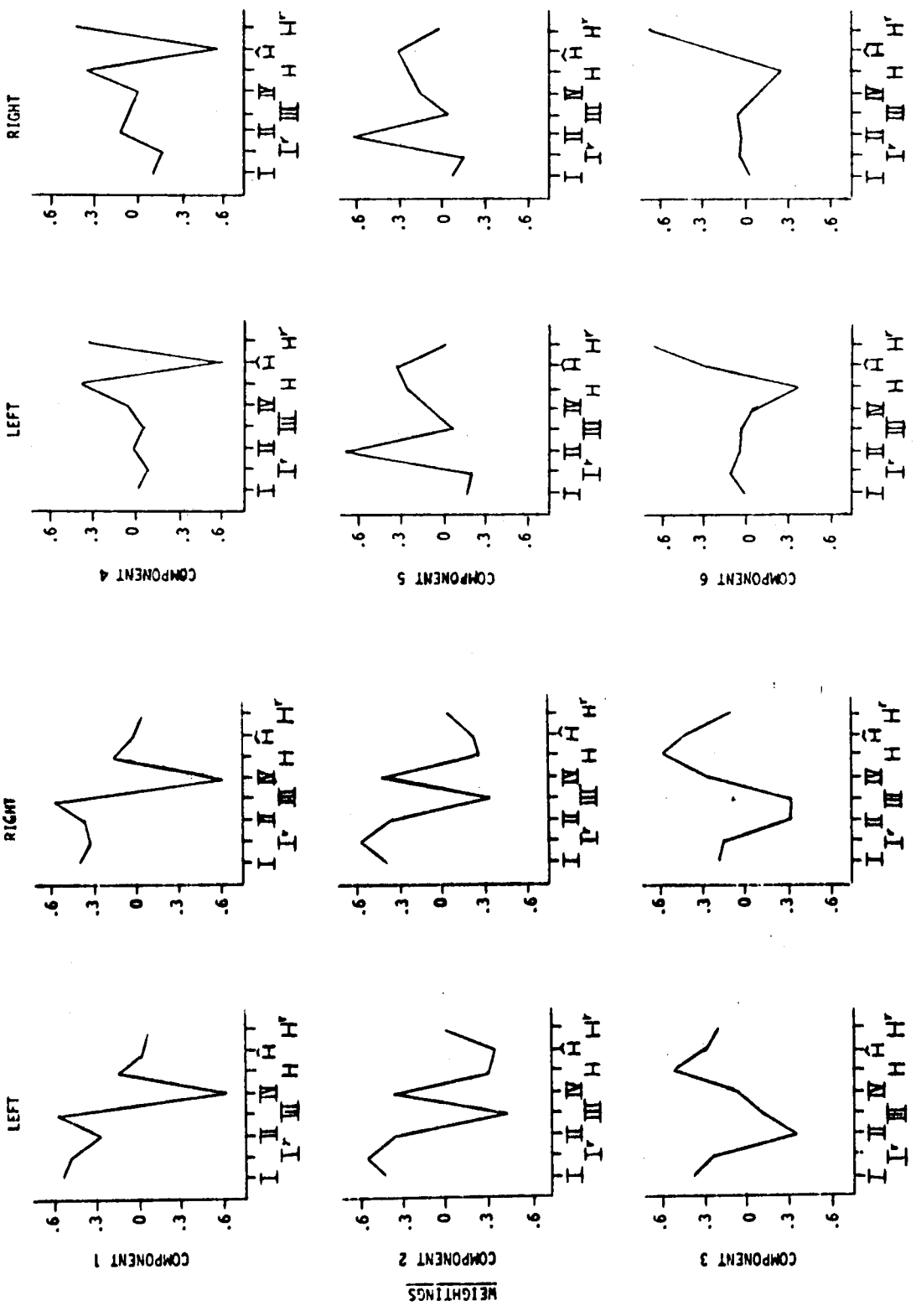


Figure 6. Principal Components of Palms in Males

Table 6. Component Scores for Loops on Palmar Areas of Left and Right Hands

	FEMALES						MALES					
	1	2	3	4	5	6	1	2	3	4	5	6
Left:												
I	-.03	.75	.01	.01	-.07	.06	.52	.41	.40	.00	-.15	-.01
I^r	-.14	.73	-.08	-.08	-.01	.19	.50	.54	.25	-.09	-.20	.10
II	.22	.03	-.45	.43	.57	-.03	.28	.34	-.35	.03	.68	.04
III	.69	.13	-.06	-.24	-.01	.18	.56	-.44	-.11	-.03	-.08	.02
IV	-.70	.08	-.07	.29	.10	-.09	-.61	.41	.08	.09	.11	-.04
H	.35	.06	.36	.58	-.20	.34	.14	-.31	.50	.41	.26	-.37
$\hat{H}$	.03	.01	.61	-.24	.56	.08	-.01	-.34	.32	-.60	.33	.23
H^r	-.02	.18	.31	.36	-.06	-.55	-.03	-.00	.22	.36	-.00	.66
Right:												
I	-.08	.73	.06	-.03	-.01	-.12	.41	.42	.19	-.10	-.08	-.05
I^r	-.18	.70	-.04	-.11	.00	.12	.33	.58	.16	-.17	-.15	.02
II	.22	.13	-.53	.38	.53	-.05	.34	.39	-.31	.13	.63	.02
III	.76	.22	-.01	-.17	.01	-.15	.60	-.34	-.33	.04	-.05	.03
IV	-.76	-.04	.02	.20	.01	.24	-.62	.42	.26	-.00	-.15	-.09
H	.31	.02	.36	.64	-.09	.36	.26	-.28	.55	-.41	-.23	-.26
$\hat{H}$	-.13	.01	.55	-.18	.63	.05	.02	-.26	-.42	-.59	.32	.19
H^r	.13	.14	-.32	.26	-.08	-.56	-.04	-.06	.12	.43	.05	.63

areas of the palm.

In males Component 2 contrasts thenar/I, II and IV areas with II and hypothenar areas. Component 4 sharply contrasts H and H^r areas with $\hat{H}$. Component 5 emphasizes interdigital area II with a very high positive weighting, and Component 6 contrasts H with $\hat{H}$ and H^r areas.

Knussman (1969) found two factors influencing palmar configurations which are pertinent to the present study. Through factor analysis of ridge counts on palms he found one factor influencing ridge counts of interdigital areas II and IV and one influencing those of interdigital area III. However, these do not appear to be generally equivalent to any of the principal components extracted in the present analysis.

II. RELATIONSHIPS BETWEEN PRINCIPAL COMPONENTS AND SELECTED VARIABLES

The scores for each individual for the first six principal components of fingers and of palms were used in subsequent analyses in place of the original dermatoglyphic data. Each principal component was tested by analysis of variance to detect dermatoglyphic differences between persons of varying height, weight, handedness, armfolding, color vision, tongue rolling ability, cerumen type, P.T.C. taste reaction and area of birth. Analysis of the data revealed that five traits showed significant heterogeneity with respect

to one or more dermatoglyphic components: height, handedness, handclasping, armfolding and P.T.C. taste reaction. Table 7 summarizes the results of the analysis of variance.

Height

The distribution of individuals by height is presented in Table 8. Height showed a correlation to finger Component 4 in females ($F=1.67$; $d.f.=15,551$; $p<0.05$) but no correlation to dermatoglyphic configurations in males. Finger Component 4 in females reflects bimanual asymmetry on digits II and III and the presence of ulnar loops on the thumbs of both hands. Mean scores for this component are graphed by height in Figure 7.

The data reflect a tendency for very short females to show increased bimanual asymmetry on digits II and III. Subjects under five feet tall show a marked trend toward the presence of radial loops on digits II and III of the left hand and ulnar loops on digits II and III of the right hand, as well as ulnar loops on both thumbs.

In humans height is a continuous trait which is probably determined by polygene inheritance (Burns 1972). It is, however, affected by environment through agents such as nutrition or disease. Dermatoglyphic asymmetry, however, has a low heritability, at least in terms of finger ridge counts (Holt 1954, Singh 1970). It may be that certain environmental disturbances in the uterus affect both height and

Table 7. Levels of Significant Association from Analysis of Variance

Trait	Sex	Principal Components of Fingers						Principal Components of Palms					
		1	2	3	4	5	6	1	2	3	4	5	6
Height	F	-	-	-	.050	-	-	-	-	-	-	-	-
	M	-	-	-	-	-	-	-	-	-	-	-	-
Weight	F	-	-	-	-	-	-	-	-	-	-	-	-
	M	-	-	-	-	-	-	-	-	-	-	-	-
Handedness	F	-	-	-	-	-	.050	-	-	-	-	-	-
	M	-	-	-	-	-	-	-	.025	-	-	-	-
Handclasping	F	.050	-	-	-	.025	-	-	-	.058	-	-	-
	M	-	-	-	-	-	-	-	-	-	-	-	-
Armfolding	F	-	-	-	-	-	.050	-	-	-	-	-	-
	M	-	-	-	-	-	-	-	-	-	-	-	-
Color Vision	F	-	-	-	-	-	-	-	-	-	-	-	-
	M	-	-	-	-	-	-	-	-	-	-	-	-
Tongue Rolling	F	-	-	-	-	-	-	-	-	-	-	-	-
	M	-	-	-	-	-	-	-	-	-	-	-	-
Cerumen Type	F	-	-	-	-	-	-	-	-	-	-	-	-
	M	-	-	-	-	-	-	-	-	-	-	-	-
P.T.C. Tasting	F	-	.025	-	-	-	-	-	-	-	-	-	-
	M	-	-	-	-	-	-	-	-	-	-	-	-
Area of Birth	F	-	-	-	-	-	-	-	-	-	-	-	-
	M	-	-	-	-	-	-	-	-	-	-	-	-

Table 8. Distribution of Subjects by Height

Height	Females	Males
<4' 11"	5	1
4' 11"	3	-
5' 0"	17	-
5' 1"	20	-
5' 2"	47	-
5' 3"	72	-
5' 4"	97	4
5' 5"	65	2
5' 6"	90	7
5' 7"	53	22
5' 8"	61	29
5' 9"	16	32
5' 10"	8	58
5' 11"	9	62
6' 0"	3	63
6' 1"	-	46
6' 2"	1	38
6' 3"	-	13
6' 4"	-	7
6' 5"	-	3
6' 6"	-	1
>6' 6"	-	1
Total	567	389

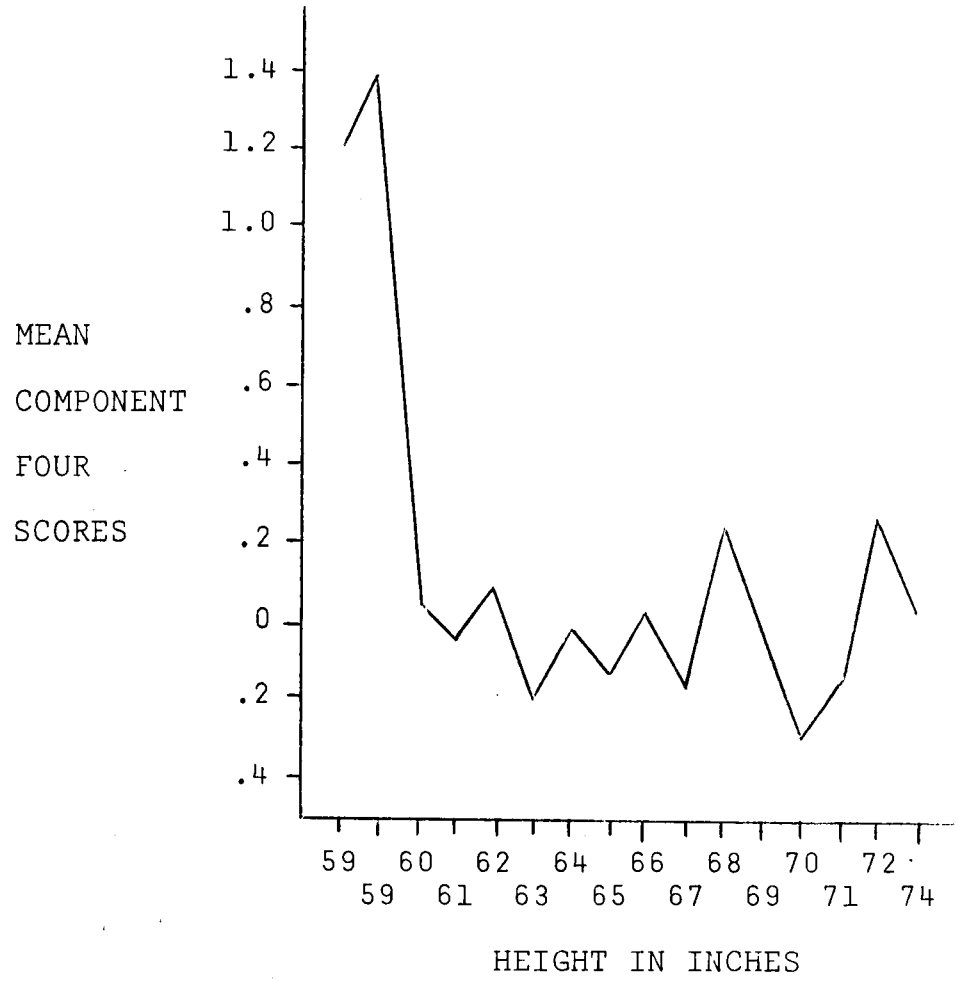


Figure 7. Mean Component 4 Scores for Fingers in Females by Height

dermatoglyphic asymmetry. However, from Table 8 one can see that the number of extremely short subjects is relatively small compared to the total size of the sample. Therefore, the statistical differences found between individuals of varying height may be a result of sampling rather than an actual biological trend in the population.

Weight

Weight of subjects in the sample population showed no correlation with any dermatoglyphic component for males or females. Thus, the individuals in the various weight categories were not significantly different from each other with respect to the dermatoglyphic characteristics expressed in the principal components. Table 9 shows the distribution of subjects by weight.

Handedness

As can be seen in Table 10, two components showed a relationship with handedness, one for females and the other for males. Finger Component 6 was significantly associated with handedness in females ($F=3.91$; d.f.=1,565; $p<0.05$), and palm Component 2 was significantly associated with handedness in males ($F=5.29$; d.f.=1,387; $p<0.025$).

Finger Component 6 in females contrasts radial and ulnar loops on digit II of right and left hands (bimanual asymmetry). This component separates groups of individuals having radial loops on digit II of their left hands and ulnar loops on digit II of their right hands from groups of individuals having ulnar loops on digit II of their left hands and radial loops on digit II of their right hands, with the former group tending to receive a higher score for this component than the latter. Mean scores for Component 6 indicate that left handed females tend to have radial loops on

Table 9. Distribution of Subjects by Weight

Weight in lbs.	Females	Males
<76	-	1
76 - 85	-	-
86 - 95	7	-
96 - 105	42	-
106 - 115	125	1
116 - 125	169	7
126 - 135	107	25
136 - 145	50	42
146 - 155	31	80
156 - 165	23	60
166 - 175	6	55
176 - 185	5	50
186 - 195	1	19
196 - 205	-	21
206 - 215	1	13
216 - 225	-	5
226 - 235	-	6
236 - 245	-	2
245 - 255	-	2
>255	-	-
Total	567	389

Table 10. Distribution of Subjects by Handedness and Scores for Significantly Associated Components

	Females			Males		
		Finger Component 6			Palm Component 2	
Handedness	Number of Subjects	Mean	S.D.	Number of Subjects	Mean	S.D.
Left	47	0.28	0.95	28	0.20	1.17
Right	520	-0.03	1.00	360	-0.02	0.99
Total	567			389		

digit II of their left hands and ulnar loops on digit II of their right hands; the reverse would tend to occur in right handed females. These results correspond to those obtained by Newman (1934), who found that radial loops are more frequent on the left hand of left handers and on the right hand of right handers.

Holt (1954) suggested that asymmetry in ridge counts is caused by environmental influences, and Singh (1970) showed that asymmetry of finger ridge count has a small but significant hereditary component, with most of the observed asymmetry probably due to the effect of environment and chance. It is probable that asymmetry of pattern type also has a low heritability. Digit II makes the greatest contribution to asymmetry (Jantz 1975, Cummins and Midlo 1943), and

it is this factor which is reflected by finger Component 6 in females. Thus, the significant difference between right and left handers with respect to bimanual asymmetry of pattern type on digit II suggests that disturbances in the uterine environment during the period of ridge formation may influence handedness as well as dermatoglyphic asymmetry.

Component 2 of palms in males contrasts the higher frequency of patterns in palmar areas II, IV and thenar/I against the lower frequency of patterns in area III and the hypothenar area. Left handed males received a positive mean component score and right handers received a negative score, suggesting that left handers tend to have patterns more frequently in thenar/I, II, and IV, whereas right handers have a greater frequency of patterns in area III and the hypothenar area.

These results partially agree with those of previous studies on palmar configurations and handedness. Bettman (cited in Rife 1955), Leche (1933), Newman (1934), Cromwell and Rife (1942), and Rife (1955) show increases in the frequencies of patterns in the thenar/I area among left handers. Leche and Newman noted a greater number of patterns in interdigital area II in both hands of left handers than were found in right handers. Leche also observed more patterns in interdigital area IV on both hands of left handers than observed on right handers, which agrees with our results. However, Newman's results differed with regard

to this character, showing a decrease of patterns in area IV in both hands of left handers. Our results differ from those of Leche, Newman, and Cromwell and Rife regarding the hypothenar and third interdigital area. They found an increase of patterns among left handers in the hypothenar and third interdigital areas, but our results indicate a low frequency of patterns in those areas among left handers.

Cummins et al. (1931) classified patterns in the hypothenar, second and third interdigital areas as dextral characters (occurring more frequently in right hands) and thenar/I and interdigital IV patterns as sinistral characters (occurring more frequently in left hands). Previous studies have observed a trend toward accentuation of dextral characters in left handers (Leche 1933, Newman 1934, Rife 1955). The present study supports this idea with regard to increased frequency of patterns in interdigital area II; however, this study differs with regard to the other dextral characters, showing a higher frequency in left handers of the sinistral characters (increased frequency of patterns in thenar/I and interdigital area IV). The different results obtained in the various studies may be due to the different criteria used in determining handedness in the sample populations. The present study divided the population into left handers and right handers on the basis of writing hand. Leche, however, used a series of tests to separate individuals having dominance of the left side,

including writing, cutting with scissors, sorting of beads, sighting eye, kicking foot and arm length. Her control population consisted of a mixed group of right handers, left handers, and ambidextrous individuals. Newman distinguished lateral dominance by performance on tests such as writing, throwing, catching, kicking, and high jumping. Rife also used several tests to determine handedness. The method of determining handedness may have influenced the results of the various studies by dividing the sample populations differently.

Several studies have been made concerning the inheritance of palmar dermatoglyphics. Rife (1941) found evidence of autosomal linkage between handedness and patterns on interdigital IV. A later study by Rife and Bansal (1963) found that a single dominant gene with approximately 86% penetrance is responsible for vestiges and accessory triradii in interdigital areas II and IV. They suggested that the gene is highly variable in expressivity, ranging from a vestige in only one area on one hand to triradii on areas II and IV on both hands of an individual. Loesch (1971) proposed that $\hat{H}$ and II loops are determined mainly by single genes, those for the loops being of homozygous recessive form, whereas H and H^r loops are almost entirely determined by environmental influences. Loesch also found that loops I + I^r + II + III + H combined have a high heritability.

Although such studies do not agree on the exact mode

of inheritance, they do give evidence of genetic control over loops in II, IV and $\hat{H}$. The present study indicated that left handers have a higher frequency of patterns in thenar/I, II and IV. The correlation between handedness and the incidence of such dermatoglyphic configurations suggests that handedness may also have a genetical component which operates under the influence of the same genes or genes linked to those controlling the palmar patterns.

It is likely that handedness results from the interaction of various processes, including heredity, uterine environment and behavioral conditioning in the young child. Further study is needed to understand the extent to which each of the processes affect the outward expression of lateral dominance.

Handclasping

Left and right female handclaspers differed significantly with respect to finger Component 1 ($F=4.38$; d.f.=1,565; $p<0.05$), finger Component 5 ($F=5.12$; d.f.=1,565; $p<0.025$), and palm Component 3 ($F=3.62$; d.f.=1,565; $p<0.058$). Males, however, showed no dermatoglyphic diversity. Table 11 shows the distribution of subjects by handclasping and mean component scores.

Analysis of finger Component 1 in females, which reflects overall pattern intensity, suggests that left handclaspers tend to have a higher pattern intensity than right

Table 11. Distribution of Subjects by Handclasping and Scores for Significantly Associated Components

	Males	Females					
			Finger Component 1		Finger Component 5		Palm Component 3	
Handclasping	Number of Subjects	Number of Subjects	Mean	S.D.	Mean	S.D.	Mean	S.D.
Left	187	273	0.09	0.94	-0.10	0.97	0.08	0.93
Right	202	294	-0.08	1.04	0.09	1.03	-0.08	1.06
Total	389	567						

handclaspers. Since pattern intensity has been shown to be influenced by heredity (Mukherjee 1966), the dermatoglyphic difference between right and left handclasping females gives evidence of genetic control over handclasping through genetic linkage or a pleiotropic effect acting on both traits.

Finger Component 5 in females contrasts the frequency of patterns on the radial and ulnar sides of the hand. Mean scores for Component 5 indicate that right handclaspers tend to have a higher frequency of patterns on the ulnar side of the hand and a lower frequency on the radial side of the hand; left handclaspers tend to have the opposite distribution of patterns. Bonnevie (1924) and Roberts and Coope (1975) have noted differential development of radial and ulnar sides of the hand. The genetics of independent development of dermatoglyphics on either side of the hand needs further study.

Component 3 for palms in females contrasts the frequency of patterns in interdigital area II with frequencies of patterns in the hypothenar area. Analysis of the data indicates that left handclaspers tend to have fewer patterns in interdigital area II and more patterns in the hypothenar area, especially $\hat{H}$ loops. Right handclaspers are likely to have patterns more frequently on interdigital area II and less frequently on the hypothenar area. As mentioned earlier in the discussion on handedness, Loesch (1971) suggested that II and $\hat{H}$ loops are determined by single homozygous recessive

genes. The relationship found between these dermatoglyphic features and handclasping again indicate that the handclasping trait has a genetic component.

The results of this study support the findings of Loveland (1973), who studied the inheritance of handclasping in 86 families from Tennessee. She found evidence of parental influence on the type of handclasping encountered among their children in the Tennessee families and suggested the possible involvement of genetic factors.

Armfolding

In the female sample left and right armfolders differed significantly with respect to Component 6 for fingers ($F=4.50$; d.f.-1,565; $p<0.05$). No association proved significant in the male sample, as can be seen in Table 12. Finger Component 6 in females reflects bimanual asymmetry on digit II. The positive mean component score for left armfolders indicates that they tend to have radial loops on digit II of their left hands and ulnar loops on digit II of their right hands; the reverse distribution of patterns would be more likely to occur in right armfolders.

Finger Component 6 also showed a relationship to handedness in females and is discussed more fully in the previous section on handedness. Previous studies have shown no genetic influence on the armfolding trait (Loveland 1973) Rhoads and Damon 1973, Weiner 1932). Since bimanual asymmetry

Table 12. Distribution of Subjects by Armfolding and Scores for Significantly Associated Components

	Males	Females		
			Finger Component 6	
Armfolding	Number of Subjects	Number of Subjects	Mean	S.D.
Left	231	296	0.09	0.97
Right	158	271	-0.09	1.02
Total	389	567		

also has a low heritability, at least in terms of finger ridge counts, it is not likely that the association between armfolding type and finger Component 6 reflects genetic control over either trait. However, if environmental influences during prenatal development affects the symmetry of the dermal ridges, it may be that such environmental disturbances also affect laterality as expressed in armfolding.

Color Vision, Tongue Rolling, Cerumen, P.T.C. Tasting

Table 13 shows the distribution of individuals in the various categories of color vision, tongue rolling ability and cerumen type. Analysis of variance revealed no significant associations between the principal components from dermatoglyphic data and these three traits. It is

possible that these results may be due to the small sample size, especially for color blindness and wet cerumen type.

Table 13. Distribution of Subjects by Color Vision, Tongue Rolling Ability, and Cerumen Type

	Color Vision		Tongue Rolling		Cerumen	
Sex	Abnormal	Normal	Non-Roller	Roller	Dry	Wet
Females	1	566	137	430	43	524
Males	15	374	108	281	57	332
Total	16	940	245	711	100	856

However, in females P.T.C. taste reaction was significantly associated with Component 2 of fingers ($F=5.88$; d.f.=1,565; $p<0.025$), as may be seen in Table 14. This component contrasts the radial and ulnar sides of the fingers in both hands, with ulnar loops having a strong positive weighting and radial loops having a strong negative weighting. The positive mean component score for non-tasters and the negative score for tasters indicate that non-tasters tend to have a higher frequency of ulnar loops on their fingers, whereas tasters tend to have more radial loops.

Previous studies have found no evidence of linkage between P.T.C. tasting ability and finger ridge count. (Mohr 1954, Veale 1965, Pons 1956). However, this author is not

Table 14. Distribution of Subjects by P.T.C. Taste Reaction and Scores for Significantly Associated Components

	Males	Females		
			Finger Component 2	
Reaction	Number of Subjects	Number of Subjects	Mean	S.D.
Non-tasters	117	187	0.14	0.95
Tasters	272	380	-0.07	1.02
Total	389	587		

aware of any studies testing for linkage between P.T.C. tasting and inheritance of radial loops on the fingers. Sekla (1963) suggested that radial loops were inherited as a simple dominant trait. P.T.C. tasting ability is also the expression of a dominant genotype. A study by Johnston et al. (1966) using a sample of elementary school children from Philadelphia, Pennsylvania, showed retarded height and skeletal maturation rates in non-tasters. It may be that the P.T.C. genotype exerts an influence on the developing organism, which is reflected in the dermatoglyphics. Finger Component 2 in males also contrasts the radial and ulnar sides of the fingers. Although the difference between male P.T.C. tasters and non-tasters is not statistically significant, the direction of the scores for Component 2 is similar to that of females; i.e., tasters have a higher frequency of radial loops than non-tasters. Study of a larger male sample

might show a significant relationship between these traits in males as well as in females.

Area of Birth

No heterogeneity among students from different areas of the United States is suggested by analysis of variance. Thus, although a greater number of students in the sample were born in Tennessee, the sample population represents a generally homogeneous group of American Whites with respect to the dermatoglyphic traits being studied. The frequency distribution of individuals by area of birth is shown in Table 15.

Table 15. Distribution of Subjects by Area of Birth

Area of Birth	Females	Males
Tennessee	358	251
Southeastern U.S.	108	67
Other	101	71
Total	567	389

CHAPTER V

DISCUSSION

The results presented here give insights into both the nature of dermatoglyphic variation in humans and the relationships between this dermatoglyphic variation and height, weight, laterality and four genetic polymorphisms. By analyzing the dermatoglyphic data into principal components, several aspects of dermatoglyphic variation have been made available for analysis, including pattern intensity, relationships between the radial and ulnar sides of the fingers and of the hand, the expression of bilateral asymmetry in finger patterns, and associations between patterns on various areas of the palm, especially II, IV and hypothenar areas. No attempt has been made in this study to establish equatable biological components as Roberts and Coope (1975) did with finger ridge counts. Nonetheless, the principal components point out relationships present in the data and can serve as reference points for future research in identifying biological tendencies in the development of ridged skin.

No evidence of any association between dermatoglyphics and weight, color vision, tongue rolling ability, cerumen type, or area of birth was found in the data. However, different dermatoglyphic configurations were found in subjects of differing height, handedness, handclasping,

armfolding and P.T.C. tasting ability. It is interesting that three of these traits--handedness, handclasping, and armfolding--deal with lateral dominance. The data indicate the possibility of genetic control in the expression of handedness and handclasping. Left handed males showed patterns more frequently on thenar/I, II and IV areas of the palm, and right handed males tended to have more patterns in area III and the hypothenar area. Female left handclaspers had a higher pattern intensity on fingers than right handclaspers; left handclaspers also tended to have fewer patterns in interdigital II and more patterns in the hypothenar, with the reverse distribution more likely to occur in right handclaspers. Pattern intensity and the presence of loops in interdigital areas II, IV and $\hat{H}$ appear to have a genetic basis, and the present study suggests that handedness and handclasping may be genetically linked to these traits or are acted upon pleiotropically by the same genes.

Left and right handclasping females also showed a difference in the distribution of patterns on the radial and ulnar sides of the hand; left handclaspers had a higher frequency of patterns on the radial side of the hand and right handclaspers on the ulnar side of the hand. A number of congenital limb malformations point to the independence of development of the radial from that of the ulnar side of the hand (Roberts and Coope 1975). Further study is needed on the sequences of embryological development in the formation

of dermal ridges on the radial and ulnar sides of the hands (and fingers) in order to better understand the independence or interdependence of such growth processes and their underlying hereditary nature.

Bimanual asymmetry appears to be expressed differently on the fingers of left and right handed subjects and of left and right armfolders. In females radial loops were found more frequently on the left hand of left handers and on the right hand of right handers, as well as on left digit II of left armfolders and on right digit II of right armfolders. Since bimanual asymmetry probably has a low heritability, disturbances in the uterine environment during the period of ridge formation may have some influence on the expression of handedness and armfolding as well as on asymmetry. Genetic makeup, prenatal environment and behavioral conditioning may each play a part in the expression of lateral dominance, but the extent to which they interact with each other is yet to be fully understood.

The results of this study also reveal a tendency for very short females to express greater bimanual asymmetry on digits II and III than females of average height. It is possible that environmental factors which produce dermatoglyphic asymmetry also affect height. However, as mentioned previously, the subject population had relatively few individuals of extreme heights, and the statistical relationship between height and dermatoglyphics may result from sampling error.

One of the interesting findings of the study is that female P.T.C. tasters tended to have a higher frequency of radial loops on the fingers than non-tasters. It may be that the P.T.C. genotype influences the development of the organism, thereby affecting dermatoglyphics.

Analysis of the data revealed a sexual difference in the manifestation of dermatoglyphic characteristics and their relationships to the other traits examined in this study. It should be noted that out of eight statistical relationships occurring in the data, seven occur in females and only one in males. Six of the seven associations found in females are related to dermatoglyphics of fingers and the seventh to palms. Since six finger components and six palm components were analyzed separately by sex for correlation with ten variables, by chance alone one would expect to find three significant statistical relationships ($p<0.05$) occurring in each separate analysis of data. Thus, the number of associations occurring in the finger data in females exceeds the expected frequency, but for palms in both sexes the associations could have resulted from chance fluctuations in the data.

Some Additional Problems

As a result of this study several problems for further research can be suggested. The principal components

derived from the data point to relationships between various dermatoglyphic characteristics on the fingers and palms. Some of these characteristics have already been studied for genetic and environmental origins, but others have not. Investigation of the biological trends reflected by the principal components and family studies to determine the genetic and environmental forces acting upon them could provide much information about dermatoglyphic variation. Related research examining these dermatoglyphic traits in various Primate populations might help illuminate biological distances and evolutionary trends among different populations.

Another problem presented by the results of this study concerns the dermatoglyphic differences between females and males. It could be helpful to do the same study on a different population to see if similar results occur, supporting the possibility of sex-linked dermatoglyphic characteristics.

A third problem area which appeared during this study is a lack of information on several details of embryological development of ridged skin. Research is needed to better understand the differential development of radial and ulnar sides of the fingers and of the hand. Also more work is needed on the uterine conditions which affect bimanual asymmetry of pattern types.

Summary

A study was conducted on 567 female and 389 male Caucasian students at The University of Tennessee, Knoxville, in an attempt to distinguish the principal components of dermatoglyphic variation and their relationships to height, weight, laterality, area of birth, and four genetic polymorphisms--color vision, tongue rolling ability, P.T.C. taste reaction, and cerumen type. Six principal components for fingers and six for palms derived from the dermatoglyphic data for females and males were tested by analysis of variance for correlation with each trait. Subjects of differing height, handedness, handclasping, armfolding and P.T.C. taste sensitivity showed significantly different dermatoglyphic characteristics.

Extremely short females showed a tendency toward increased bimanual asymmetry on digits II and III. However, the number of short subjects in the sample was too small for conclusive results.

Radial loops appeared more frequently on the left hands of left handed females and on the right hand of right handed females. Left handed males showed a greater frequency of patterns in palmar areas II, IV and thenar/I, whereas right handers had patterns more frequently in III and the hypothenar area. Since II, IV and $\hat{H}$ loops have been shown to have a hereditary component, it is suggested that the relationship between these traits and handedness gives

evidence of genetic influence in determining handedness.

Female left handclaspers showed a higher pattern intensity than right handclaspers. They also indicated a tendency to have fewer patterns in interdigital area II and more patterns in the hypothenar area, with the reverse distribution occurring in right handclaspers. Since these dermatoglyphic characteristics appear to be genetically controlled, the data indicate the influence of a genetic component in the expression of handclasping. In addition to these results, left handclasping females manifested a higher frequency of patterns on the radial side of the hand and right handclaspers on the ulnar side of the hand, possibly reflecting independent development of the two sides of the hand.

Bimanual asymmetry was expressed differently in female armfolders, with left armfolders tending to have radial loops on digit II of their left hands and ulnar loops on digit II of their right hands; right handclaspers revealed the opposite distribution of patterns.

A correlation was found between P.T.C. tasting ability and radial loops on the fingers of females. Tasters tended to have a higher frequency of radial loops, and non-tasters had more ulnar loops.

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APPENDIX

APPENDIX

ANTHROPOLOGY HUMAN VARIATION QUESTIONNAIRE

You are requested to give as much of the information listed below as possible. It is to be used in obtaining human genetic information, and the larger the number of people in the sample, the more representative it will be of the population as a whole. In the interests of being as frank as possible, do not put your name on the questionnaire sheet. We are not interested in tracing any one piece of information to any one individual.

Circle the correct answer to each question.

1. Your sex:
   a. Male
   b. Female

2. Your racial background:
   a. American Negro
   b. American White
   c. American Indian
   d. Other (Specify)

3. Your twin status:
   a. not a twin
   b. You have a twin of the same sex
   c. You have a twin of the opposite sex
   d. Your twin is in this class
   e. You are a member of a set of triplets, or a group based on a higher order of multiple births (describe).

4. Your height:
   a. less than 4'11" (specify)
   b. 4'11"
   c. 5'0"
   d. 5'1"
   e. 5'2"
   f. 5'3"
   g. 5'4"
   h. 5'5"
   i. 5'6"
   j. 5'7"
   k. 5'8"
   l. 5'9"
   m. 5'10"
   n. 5'11"
   o. 6'0"
   p. 6'1"
   q. 6'2"
   r. 6'3"
   s. 6'4"
   t. 6'5"
   u. 6'6"
   v. greater than 6'6" (specify)

5. Your weight:
   a. less than 76 lbs.
   b. 76-85
   c. 86-95
   d. 96-105
   e. 106-115
   f. 116-125
   g. 126-135
   h. 136-145
   i. 146-155
   j. 156-165
   k. 166-175
   l. 176-185
   m. 186-195
   n. 196-205
   o. 206-215
   p. 216-225
   q. 226-235
   r. 236-245
   s. 246-255
   t. more than 255 lbs.

6. Handedness (how you classify yourself):
   a. right handed
   b. left handed
   c. ambidextrous (use right and left hands equally well)

7. Handedness of mother:
   a. right handed
   b. left handed
   c. ambidextrous

8. Handedness of father
   a. right handed
   b. left handed
   c. ambidextrous

9. Hand with which you write:
   a. right hand
   b. left hand
   c. can write with either equally well

10. Handclasping:
    a. clasp with right thumb uppermost
    b. clasp with left thumb uppermost
    c. no preference

11. Armfolding:
    a. fold with right arm uppermost
    b. fold with left arm uppermost
    c. no preference

12. Color vision:
    a. unable to discriminate any color (or have considerable difficulty in doing so)
    b. red-green color blind
    c. normal color vision

13. Tongue rolling ability:
    a. unable to roll tongue into trough shape
    b. able to roll tongue into trough

14. Ear wax:
    a. dry (ear wax is dry and crumbly)
    b. wet (ear wax is wet and sticky)

15. PTC Taste reaction:
    a. unable to taste PTC saturated paper
    b. PTC paper has bitter taste
    c. PTC has definite taste other than bitter (describe)

16. Midphalangeal hair (hair on middle segment of digits)
    a. hair on digit 4
    b. hair on digit 4 and 3
    c. hair on digit 4, 3 and 2
    d. hair on digit 4, 3, 2, and 5
    e. some other combination (describe)

Fill in blanks with appropriate answer

17. Number of siblings living or deceased (do not include yourself)
    a. No. of brothers _____
    b. No. of sisters _____

18. Place of birth of:
    a. yourself - city or town _____;
       county _____; state _____;

       country _____.

    b. Your father - city or town _____;
       county _____; state _____;

       country _____.

    c. Your mother - city or town _____;
       county _____; state _____;

       country _____.

VITA

Letitia Lowe Oliveira was born on November 17, 1947, in Jackson, Mississippi, where she graduated from Murrah High School in 1965. She attended Agnes Scott College in Decatur, Georgia and graduated cum laude in June, 1969, with a Bachelor of Arts degree in music.

Upon completion of college she was employed as a computer operator and programmer by I.B.M. in Atlanta, Georgia, during which time she also worked as organist and director of three choirs at Rehoboth Presbyterian Church in Decatur, Georgia.

In the fall of 1972 she moved with her husband to Knoxville, Tennessee, where she was employed as a computer programmer at The University of Tennessee. She entered the Graduate School at The University of Tennessee in March, 1973, on a part-time basis and in September, 1974, as a full-time student, receiving the Master of Arts degree with a major in anthropology in December, 1975.

She is a member of Phi Beta Kappa, Phi Kappa Phi, and the American Association of Physical Anthropologists.

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