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Diversity in Palmar Pattern Ridge Counts Among 12 Iranian Populations

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ABSTRACT Bilateral palmar prints of 604 male individuals from 12 Iranian groups, six Mongoloid and six Caucasoid, have been analyzed for palmar pattern ridge counts (PPRC). Highly significant variation has been observed in the size of the palmar patterns in all the configurational areas among the Iranian groups. The distance analysis based on PPRCs differentiated the Iranian Mongoloid from the Iranian Caucasoid groups into distinct clusters. The pattern of differentiation based on PPRCs explained the ethnohistoric relationships between the Iranian groups as well as between the Iranian and the 20 Caucasoid groups from India much better than the palmar pattern frequencies. The results of this study demonstrate the existence of variation in the size of the palmar patterns across different populations within an ethnic group, as well as that among different ethnic groups, and seems to be a better indicator of interpopulational diversity than the palmar pattern frequencies.

Recently Malhotra et al. (1981, 1982) extended ridge count technique to true patterns in all the palmar configurational areas and defined a quantitative measure, total palmar pattern ridge count (TPPRC). The trait TPPRC is the sum of the single ridge counts (highest, when double or triple counts are found for any pattern) on the ten configurational areas of an individual. Genetic investigations carried out by Malhotra et al. (1981, 1982), Malhotra and Rao (1982), Borecki et al. (1985), and Gilligan et al. (1985) showed that 1) the pattern ridge counts on the individual areas of the palm are weakly associated and the counts of interdigital patterns of I_3 and I_4 are negatively correlated, 2), the traits TPPRC and total finger ridge counts (TFRC) are insignificantly associated, and 3) the trait TPPRC as well as the counts in individual palmar areas are moderately determined by heredity. Malhotra et al. (1983, 1986) studied affinities between populations from western India with respect to palmar pattern ridge counts (PPRCs) and found a general agreement between the known ethnohistoric relationships and the pattern of clustering based on PPRC distances. It is noteworthy that Malhotra et al. (1986) found stronger congruence between PPRC distances and distances based on genetic markers compared to that between genetic distances and those based on total finger ridge counts, total absolute finger ridge counts, and finger pattern intensity index.

These results assume further significance in view of the fact that a majority of the populations investigated in the above studies belonged to a single ethnic group, i.e., the Caucasoids, and the earlier studies (Malhotra et al., 1978; Papiha et al., 1982) showed that the genetic differentiation among these populations is rather small (average values of standard genetic distance, as defined by Nei [1975], is about 0.01). Although these

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studies demonstrated the usefulness of PPRCs in microevolutionary studies at local and regional levels, it is of considerable interest to examine if PPRCs would also be found useful in studying affinities between populations of diverse origin.

The purpose of this paper is, therefore, to examine affinites between 12 population groups of Iran. Since six of these 12 populations sampled are ethnically Mongoloids, in the first part of this paper we also examine the distributional characteristics of the palmar pattern ridge counts to see if the earlier findings hold true for all major ethnic groups of man. (Note that these traits have so far been examined only in populations of Caucasoid origin.) The other six population groups of Iran sampled in the present study are Caucasoid. To examine if the Caucasoids of Iran differ from those in the Indian subcontinent, we also compare the interpopulational distances of the Iranian groups with the 20 Dhangar caste groups based on the palmar pattern ridge counts and palmar pattern frequencies.

MATERIALS AND METHODS

Inked bilateral palmar prints of 604 males from 12 population groups belonging to the Mongoloid and Caucasoid racial stocks of Iran were collected and analyzed for palmar ridge counts after the techniques of Malhotra et al. (1981, 1982). The six Mongoloid groups investigated included five Turkman and one Kazak group. The Turkman are a large ethnic group found in Turkman Sahra, Iran, and Turkmanistan in the Soviet Union. They are divided into a number of endogamous groups. The Kazaks are also a large Mongol group and live in Kazakhistan, Soviet Union; some of the Kazaks migrated to Iran after the 1917 revolution. They share habitat with the Turkmans and are endogamous. The six Caucasion populations studied belong to the Azaris, Taleshis, and Kurdish major groups. The Azaris live in Azarbaijan and speak a Turkish dialect. The Taleshis are nomads, live in the hilly area of Gilan, and are endagamous. The Kurds, comprising several endogamous populations, are one of the biggest tribes of Iran; the population studied here belongs to the Darmaran Kurds.

The names and the sample sizes of the 12 Iranian populations are given in Table 1, and their geographical locations are shown in Figure 1.

TABLE 1. Populations studied and their sample sizes

Populations	Abbreviations used	Sample size
Mongoloid groups		
Aqtaqeh Turkman	AT	36
Hootan Turkman	HT	40
Garkaz Turkman	GT	84
Jargalan Turkman	JT	39
Korand Turkman	KT	40
Kazaks	KZ	76
Caucasoid groups		
Afjeh Azaris	AA	40
Bale-Jokeh Azaris	BA	34
Firanaq Azaris	FA	80
Kalandarq Azaris	KA	33
Taleshis	TL	63
Darmaran Kurds	DK	39

Fig. 1. Geographic locations of the populations studied. The population groups designated by numbers are 1, Aqtaqeh Turkman (AT); 2,Garkaz Turkman (GT). 3, Hootan Turkman (HT); 4, Jargalan Turkman (JT); 5, Korand Turkman (KT); 6, Kazaks (KZ); 7, Afjeh Azaris (AZ); 8, Bale-Jokeh Azaris (BA); 9, Firanaq Azaris (FA); 10, Kalandarq Azaris (KA); 11, Darmaran Kurds (DK); and 12, Taleshis (TL).

As mentioned before, Malhotra et al. (1982) discussed in detail the methodology for determining palmar pattern ridge counts (TPPRC) in five individual areas of the palm: 1) hypothenar (Hyp); 2) thenar/interdigital-I (Th/I_1); 3) interdigital-II (I_2); 4) interdigital-III (I_3); and 5) interdigital-IV (I_4); as well as their sums, total palmar pattern ridge count (TPPRC). Each of these measurements were

taken on right and left palms and TPPRC values were added for both palms to have a combined TPPRC for the individuals. On each individual palmar area the basic patterns (loops, whorls, and tented arches) are morphologically similar to the traditional digital patterns on fingertips. However, since patterns on some of these areas often involve more than two triradii (e.g., whorls in hypothenar area generally have three, instead of two, triradii), the procedure of considering the higher ridge counts of each area of Malhotra et al. (1982) was adopted here in the case where two or three counts could be measured depending on the particular pattern configurations of the areas.

Thus, based on the pattern ridge counts on the ten configurational palmar areas, a total of 13 variables were defined. These are palmar pattern ridge counts of the five individual pattern areas (Hyp, Th/I_1, I_2, I_3, and I_4, for the left and right palms) and their totals (TPPRC – right, left, and right + left). Since all of these individual palmar areas sometime lacked true patterns, each of these 13 variables were also defined including as well as excluding unpatterned areas, i.e., with and without ridge counts.

For each of the 13 variables defined above, the occurrences of zero counts (lack of pattern in a given configurational area) are found to be quite conspicuous. Inclusion of these zero counts in studying interpopulational variability seems to be problematic, since the distributions with inclusions of such zero counts produce conspicuous bimodality and hence significant departures from normality. Inclusion of zero counts, therefore, makes the results of hypotheses testing unreliable. Moreover, as shown earlier by Malhotra et al. (1983, 1986), the frequency of patterns differ, often significantly, between populations, and the estimates of mean ridge counts for a given palmar area do not reflect the actual size of the patterns when unpatterned areas are also included. For these reasons, except for showing the occurrences of lack of patterns in each palmar area in each of the 12 populations, we eliminated the zero counts from all subsequent analyses. As discussed later, this approach does not completely resolve the methodological issues related with palmar pattern size studies. Nevertheless, we demonstrate that a discrimination between ethnic groups is achieved here with greater power when the unpatterned areas are excluded by eliminating the zero counts.

Distributions and general descriptive statistics for each of these variables are computed to examine the nature of distributional properties of these palmar traits in Iranian populations. The results are described in the next section. For the sake of brevity, only the pooled results for the Mongoloid group are presented. (Further details may be obtained from the authors on request.)

Interpopulational variability in these traits is examined in three steps.

1. An analysis of variance was conducted to examine whether the 12 Iranian populations show significant differences in mean values for these palmar pattern traits following a one-way analysis of variance (Snedecor Cochran, 1976).

2. Distance analyses were conducted defining generalized distance matrices. The palmar pattern ridge count variables for the ten configurational areas (five each on each palm) for an individual were seen to be weakly associated. Therefore, the generalized distance between two populations with respect to these ten variables was defined by Pearson's coefficient of racial likeness, which is given by the formula

$$\frac{n_i + n_j}{n_i n_j} \cdot \frac{1}{m} \left[\sum_{k=1}^{m} \frac{n_{ik} n_{jk}}{n_{ik} + n_{jk}} \left(\frac{X_{ik} - X_{jk}}{s_k} \right)^2 - 1 \right],$$

where $n_i = \Sigma\, n_{ik}/m$, $n_j = \Sigma\, n_{jk}/m$, in which n_{ik} and n_{jk} denote the number of individuals on which the means X_{ik} and X_{jk} of the k-th trait for the populations i and j are based, s_k is the standard deviation of the k-th trait, and m is the number of traits used.

This definition of the coefficient of racial likeness distance makes use of an adjustment because of sample size to allow comparison of distances between pairs of populations and is called the "reduced coefficient of racial likeness" (Rao, 1952).

The distance matrix corresponding to the palmar pattern frequencies is computed by an analogous test of the above coefficient of racial likeness distance matrix for categorical data, as defined by Kurczynski (1970). Since for each of the ten palmar configurational areas the pattern frequencies were defined as occurrences of either zero (lack of

pattern) or nonzero counts (presence of pattern), this distance is simply the combined value of ten binomial proportions. Specifically, the formula used for distance between population i and j is given by

$$d_{ij} = \frac{1}{N} \cdot \sum_{k=1}^{m} \frac{(p_{ik} - p_{jk})^2}{p_k (1 - p_k)},$$

where p_{ik} and p_{jk} are the proportions of pattern frequencies for the k-th trait in i-th and j-th populations, $p_k = \Sigma\, n_{ik} p_{ik} / \Sigma\, n_{ik}$, the proportion of pattern frequencies in the pooled population, $N = \Sigma \Sigma\, n_{ik}$; n_{ik}, the sample size in the i-th population for the k-th trait, and p is the total number of traits used.

3. Lastly, to examine the interpopulational affinities with these distance matrices, we constructed dendrograms for cluster analysis, following the single linkage clustering technique, the modified unweighted pairwise group method of Nei (1975).

RESULTS

Distribution of palmar pattern ridge counts

The palmar pattern ridge counts for all the configurational areas are quantitative indicators of palmar pattern size (Malhotra et al., 1982). The distributional properties of each of these traits defined on individual palms have only been reported for some Indian populations, a number of which are of Caucasoid origin (Malhotra et al, 1982; Borecki et al., 1985). To examine the nature of these distributions in other ethnic groups, we present here the distributions only for the pooled Mongoloid group (total of populations AT, HT, GT, JT, KT, and KZ; the details for each individual population are excluded here since the general features are very similar to the pooled distributions). These are shown in Figure 2 for PPRCs of Hyp, Th/I_1, I_2, I_3, and I_4 areas. It is seen that in all areas, the frequency of zeroes (ridge counts for areas without patterns) are quite considerable, resulting in bimodal distributions. Exclusion of unpatterned areas, however, makes most of these distributions unimodal and thereby reduces both skewness and kurtosis. The distributions of PPRC for patterned areas are nearly normal for several configurational areas (e.g., I_3 and I_4).

Figure 3a–c presents the distribution of summed PPRC for the right, left, and right + left palms, respectively, for the pooled Mongoloid group. It is observed again that in the summed trait as well, the spikes caused by lack of patterns are conspicuous. Exclusion of zero counts (unpatterned areas) do not reduce the asymmetry of the distributions. In general, all of the three summed PPRCs (TPPRC R, TPPRC L, and TPPRC R + L), are significantly positively skewed. These observations are similar to the ones reported earlier (Malhotra et al., 1982; Borocki et al., 1985). The Iranian Caucasoid groups also show similar trends (details of which are not presented here).

Means and their standard deviations of palmar pattern ridge counts

In Table 2 are presented mean and standard deviations of the ridge counts on each palmar area separately for each of the 12 population groups. It is evident that in a majority of both Mongoloid and Caucasoid groups the patterns in the hypothenar area of both the palms are largest as well as most variable, and the patterns in I_2 area are the smallest and least variable. The most common sequence of the mean ridge counts and their variability, in decreasing order of magnitude on both the palms, is Hyp, Th/I_1, I_4, and I_2. The mean ridge counts in each of the palmar areas show considerable variation among the Iranian groups.

In Table 3 are presented the means and their standard errors for the total pattern ridge counts separately for right, left, and right + left palms. As in the individual areas, the means of the three summed traits also show considerable variation. For example, the total counts on the right and left palms of the Mongoloids range between 19.8 and 29.2, and 20.1 and 30.3, respectively. Among the Caucasoids the comparable ranges are 17.5 to 25.8, and 17.6 to 27.6, respectively. The summed counts for both palms combined show a range of 31.1 to 50.2 and 34.7 to 48.3 among the Mongoloids and Caucasoids, respectively. The Mongoloids, in general, tend to show slightly greater ridge counts and greater within-group variability for all three summed traits.

Bimanual differences

The bimanual differences (right − left) in the mean ridge counts of individual palmar areas are given in Table 4. It may be noted that for this analysis only those individuals are considered who possessed true patterns in a given configurational area on both the palms. It is observed that, with a few excep-

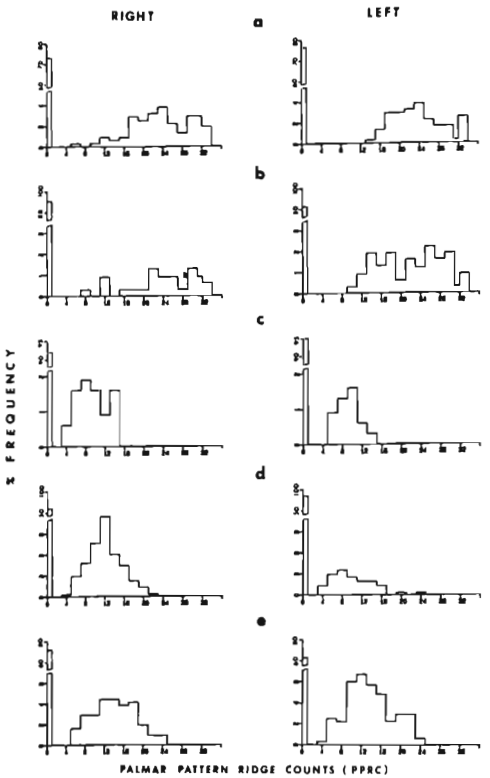

Fig. 2. Distributions of the palmar pattern ridge counts in individual pattern areas among the pooled Mongoloid sample (total of six populations: AT, HT, GT, JT, KT, and KZ). a) Hyp, b) Th/l_1, c) l_2, d) l_3, and e) L_4.

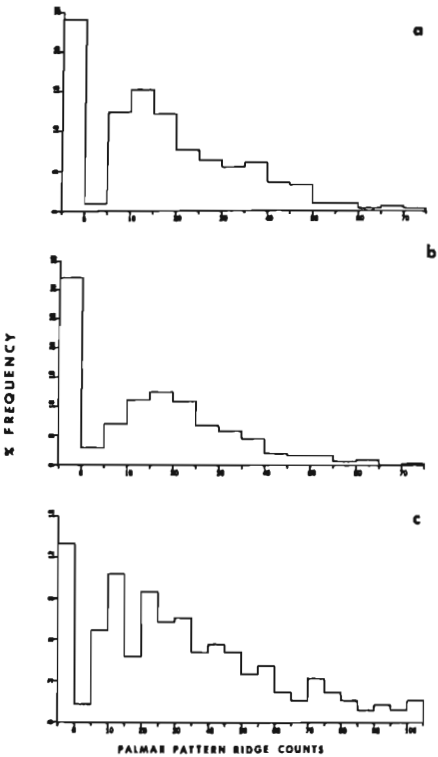

Fig. 3. Distributions of TPPRC for the a) right, b) left, and c) right + left palms in the pooled sample of Mongoloid populations.

tions, the mean ridge counts among these 12 groups for hypothenar and I_3 areas are greater on the right palms. With one exception, counts on the left Th/I_1 are greater than the right. Area I_4 also shows marked tendencies of greater ridge counts on the left palm in a majority of the groups. With respect to the means of totals of right or left palms, it is seen that while among five of the six Mongoloid groups the counts are greater on the right palm, among the Caucasoid groups higher counts are seen on the right palm.

The observed bimanual differences, however, achieve statistical significance only in the case of I_3 area (in five out of 12 groups), Th/I_1 (only among HT), and the totals right and left (only among KA).

Interpopulational differences

Analysis of variance: Before computing distances between the Iranian groups, the intergroup differences in the mean ridge counts of

TABLE 2. Means and their standard errors of palmar pattern ridge counts among 12 Iranian populations

Groups	Hyp	Th/I_1	I_2	I_3	I_4
AT					
R	26.4 ± 1.7	28.1 ± 1.5	9.0 ± 0.0	11.1 ± 1.2	14.7 ± 2.0
L	25.0 ± 1.3	26.7 ± 1.8	5.0 ± 0.0	8.8 ± 1.2	13.9 ± 1.1
HT					
R	18.3 ± 1.4	11.8 ± 1.4	9.0 ± 2.2	11.0 ± 0.8	11.0 ± 1.7
L	22.8 ± 1.9	19.2 ± 2.5	8.5 ± 0.8	7.3 ± 1.3	11.0 ± 1.2
GT					
R	24.6 ± 1.9	24.3 ± 1.5	8.8 ± 1.1	12.3 ± 0.6	13.9 ± 0.7
L	24.9 ± 1.8	22.0 ± 1.6	8.3 ± 1.8	10.9 ± 0.9	12.8 ± 0.7
JT					
R	23.9 ± 1.7	22.0 ± 4.2	10.0 ± 1.1	12.0 ± 0.9	14.3 ± 2.3
L	24.0 ± 1.7	20.7 ± 1.7	11.0 ± 2.0	12.8 ± 3.5	12.5 ± 1.4
KT					
R	26.6 ± 1.8	31.0 ± 0.0	12.0 ± 1.0	11.9 ± 0.8	14.5 ± 1.2
L	24.2 ± 1.8	20.2 ± 2.3	0.0 ± 0.0	8.9 ± 1.1	14.7 ± 1.1
KZ					
R	22.7 ± 1.6	26.0 ± 4.6	7.0 ± 1.1	10.5 ± 0.6	13.3 ± 1.0
L	21.4 ± 1.2	20.0 ± 2.2	8.0 ± 0.6	7.4 ± 0.9	14.1 ± 1.0
AA					
R	22.1 ± 1.9	16.6 ± 3.1	5.7 ± 0.9	9.2 ± 1.1	14.6 ± 1.0
L	28.7 ± 4.7	15.8 ± 2.2	7.2 ± 0.6	7.2 ± 1.0	13.6 ± 0.9
BA					
R	21.8 ± 1.5	23.3 ± 3.0	4.5 ± 0.5	11.1 ± 1.0	12.5 ± 1.0
L	20.2 ± 1.6	25.0 ± 1.1	0.0 ± 0.0	10.7 ± 1.2	11.7 ± 0.8
FA					
R	24.8 ± 1.3	16.8 ± 3.2	7.0 ± 0.8	8.6 ± 0.5	11.3 ± 0.9
L	18.6 ± 1.8	17.7 ± 3.0	7.6 ± 0.7	8.2 ± 0.8	12.3 ± 0.6
KA					
R	27.0 ± 3.0	20.2 ± 3.2	8.3 ± 1.8	9.8 ± 0.8	10.2 ± 1.2
L	23.0 ± 3.5	21.2 ± 1.4	14.0 ± 0.0	6.7 ± 1.1	7.5 ± 0.7
TL					
R	21.3 ± 1.5	25.0 ± 3.0	6.2 ± 0.9	9.1 ± 0.7	10.1 ± 1.0
L	20.6 ± 4.4	19.5 ± 3.0	5.7 ± 0.6	8.1 ± 3.9	10.4 ± 0.7
DK					
R	18.4 ± 2.4	18.7 ± 3.0	7.3 ± 1.1	9.4 ± 0.6	10.5 ± 1.0
L	17.5 ± 1.7	23.0 ± 1.2	7.6 ± 1.6	8.5 ± 1.0	9.8 ± 0.8

The abbreviations used for the traits in all tables are Hyp, hypothenar; Th/I_1, thenar/interdigital-I; I_2, interdigital-II; I_3, interdigital III; and I_4, interdigital-IV.
R, right; L, left.

TABLE 3. Means and their standard errors for the total pattern ridge counts for the right and left palms and right + left in 12 Iranian populations

Populations	TPPRC		
	Right	Left	Right + left
Mongoloid groups			
AT	29.2 ± 3.3	30.3 ± 3.1	50.2 ± 5.8
HT	20.5 ± 2.3	24.7 ± 2.6	36.1 ± 3.6
GT	23.5 ± 1.7	22.9 ± 1.9	39.1 ± 3.2
JT	24.5 ± 2.3	22.1 ± 2.4	39.7 ± 4.2
KT	24.7 ± 2.6	21.8 ± 2.2	40.1 ± 4.4
KZ	19.8 ± 1.7	20.1 ± 1.3	31.1 ± 2.6
Caucasoid groups			
AA	24.7 ± 2.1	27.6 ± 3.1	48.3 ± 4.4
BA	25.8 ± 2.3	24.3 ± 2.2	47.8 ± 4.1
FA	20.9 ± 1.7	19.8 ± 1.6	36.4 ± 3.1
KA	21.7 ± 2.7	17.6 ± 2.5	34.7 ± 2.7
TL	20.1 ± 1.8	21.8 ± 1.1	35.5 ± 2.9
DK	17.5 ± 1.9	21.7 ± 2.2	36.7 ± 3.6

TABLE 4. Bimanual differences in the mean ridge counts of individual palmar areas among 12 Iranian populations[1]

Populations	Hyp	Th/I_1	I_2	I_3	I_4	Total (R − L)
Mongoloid groups						
AT	1.86	0.75	—	5.00	1.50	1.50
HT	−5.75	−13.00**	−0.33	2.60	0.17	−2.32
GT	−0.29	−0.50	—	2.50**	0.90	1.92
JT	1.10	−0.67	—	6.00	−2.33	3.00
KT	2.80	—	—	5.71**	−0.64	3.73
KZ	2.17	1.50	−1.33	1.75	0.38	2.09
Pooled	0.52	−1.35	−0.12	3.53**	0.32	1.79*
Caucasoid groups						
AA	−7.70	2.80	−1.00	2.00*	2.07	−1.91
BA	1.92	−5.50	—	−0.20	1.00	3.11
FA	3.50	−2.00	—	−1.20	−0.96	0.50
KA	4.25	−0.80	—	3.50	2.00	4.52*
TL	1.36	—	0.33	2.37*	−0.04	−0.68
DK	2.50	−0.80	3.00	2.36**	−0.08	−3.97
Pooled	0.63	−0.62	−0.11	1.38**	0.44	−0.04
All 12 populations	0.58	−1.00	0.01	2.34**	0.40	0.80

[1]Bimanual difference is defined as the difference of ridge counts (right − left) of each individual pattern area. Individuals for which patterns are present on both palms are only included in these computations.
*P < .05.
**P < .01.

TABLE 5. F ratios to test differences of pattern ridge counts in 12 Iranian populations with respect to the individual pattern areas and their totals

Variables	F ratio	
	Right	Left
Hyp	1.87*	1.69
Th/I_1	3.09**	1.91*
I_2	2.00*	1.48
I_3	3.41**	1.75
I_4	2.77**	5.20**
Total	2.02*	2.01*
TPPRC (R + L)	2.42**	

*P < .05.
**P < .01.

the 13 palmar variables have been subjected to analysis of variance. The results of this analysis are presented in Table 5. It is evident that a considerable amount of heterogeneity exists in the Iranian groups on different palmar areas. It is highly noteworthy that in general the mean ridge counts of all the palmar configurational areas reveal significant between group differences among these Iranian groups. It is further noted that while the mean counts of each of the palmar areas of the right palm show significant differences, in the case of the left palm, significant differences are seen only for Th/I_1 and I_4 areas.

Distance analysis: From the preceding analysis it is evident that a great deal of heterogeneity exists among the Iranian populations in palmar pattern ridge counts. To understand the pattern of relationships among these groups, we computed the distance matrix based on ten palmar areas of both the palms. The reason for considering individual areas and not the trait TPPRC alone for distance analysis is due to the fact that the palmar pattern counts are rather weakly correlated; the pattern of correlations among the Iranian groups is similar to the one reported by Malhotra et al. (1986) among the Dhangars and therefore, is not reported here. The obtained values of coefficient of racial likeness (CRL) distances among the 12 groups are presented in Table 6 (below diagonal). Based on these values a dendrogram, given in Figure 4a, was constructed.

An inspection of the distance matrix and the dendrogram reveal that there are essentially two clusters: Cluster one comprises of six populations, all of which are Mongoloids except the group BA; and cluster two has five populations all of which are Caucasoids except the group HT. The groups Kalandarq Azaris (KA), however, is distinctly separated from the remaining 11 groups.

In most previous studies, interpopulational differences with respect to palmar dermatoglyphics had been examined with only palmar pattern frequencies and/or other palmar traits. To examine how the relationships among the Iranian populations compare with

TABLE 6. Values of coefficient of racial likeness (below diagonal) and Kurczynski's generalized distances (above diagonal) among 12 Iranian populations[1]

POP	AT	HT	GT	JT	KT	KZ	AA	BA	FA	KA	TL	DK
AT	—	0.08	0.07	0.09	0.10	0.13	0.18	0.14	0.10	0.08	0.16	0.18
HT	1.07	—	0.03	0.06	0.07	0.08	0.09	0.10	0.03	0.07	0.07	0.08
GT	0.19	0.51	—	0.04	0.02	0.04	0.11	0.07	0.02	0.04	0.06	0.12
JT	0.41	0.55	0.07	—	0.09	0.08	0.13	0.08	0.06	0.11	0.07	0.21
KT	0.16	0.68	0.14	0.21	—	0.06	0.13	0.11	0.03	0.04	0.07	0.14
KZ	0.23	0.41	0.17	0.34	0.22	—	0.17	0.17	0.07	0.08	0.08	0.23
AA	0.77	0.42	0.47	0.68	0.54	0.25	—	0.12	0.07	0.12	0.05	0.12
BA	0.27	0.41	0.18	0.26	0.49	0.16	0.46	—	0.06	0.13	0.06	0.18
FA	0.72	0.31	0.50	0.58	0.58	0.23	0.30	0.30	—	0.03	0.03	0.07
KA	1.13	0.59	0.80	0.67	1.07	0.90	1.03	0.49	0.59	—	0.08	0.10
TL	0.52	0.34	0.52	0.72	0.77	0.33	0.49	0.19	0.16	0.51	—	0.16
DK	0.76	0.22	0.55	0.64	0.87	0.42	0.60	0.23	0.19	0.40	0.10	—

[1]Above the diagonal entries are based on frequency of patterns in ten palmar areas, and the below diagonal entries are based on ridge counts of ten palmar areas.

the same based on palmar pattern frequencies, we also computed the palmar pattern frequencies in the same populations for all configurational areas. These are presented in Table 7. Distances were computed using these data, which are shown in Table 6 (above diagonal). The dendrogram based on this distance matrix is also shown in Figure 4b. It is clearly seen that the separation between the Mongoloid and the Caucasoid groups is far from clear on the basis of pattern frequencies alone. It is evident from the comparison of the two dendrograms of Figure 4 that for interpopulational comparisons, the palmar pattern sizes are more useful than simple frequencies.

Iranian populations compared with Dhangar castes

As mentioned earlier, so far data on palmar pattern ridge counts are available only for a few Indian populations (Malhotra et al., 1983, 1986). Therefore, it is of considerable interest to see the nature of the relationships between the Caucasian groups from India and Caucasian and Mongoloid groups from Iran.

For this purpose, we considered data on 20 Dhanger castes reported by Malhotra et al. (1986) for comparison with the present series. A distance matrix with the ten palmar pattern ridge count variables for the 32 populations (20 Dhangar caste and 12 Iranian) is constructed from which a dendrogram is drawn by methods as described earlier. For comparison, we also constructed similar distance matrix and dendrograms for these 32 populations using palmar pattern frequencies. The results of these analyses are presented only in the form of dendrograms, shown in Figure 5a for palmar pattern ridge counts and in Figure 5b for palmar pattern frequencies. It is seen that the 32 populations form two major clusters, one comprising the 20 Dhangar caste groups and the other consisting of the 12 Iranian populations. This feature is common for both ridge counts and pattern frequencies. However, within the Iranian cluster, the separation of the Mongoloid and Caucasoid groups is more clear for the palmar pattern ridge counts compared to the same seen with pattern frequencies. As expected, however, in both cases the interpopulational diversity in the 20 Dhangar castes is much smaller than that among the 12 Iranian populations.

Furthermore, this analysis demonstrates that discernible variation exists in the size of

TABLE 7. Percent frequencies of true palmar patterns among 12 Iranian populations

Populations	N		Hyp	Th/I_1	I_2	I_3	I_4
Mongoloid groups							
AT	36	R	30.56	25.00	2.78	44.45	16.67
		L	27.78	30.56	2.78	13.89	38.89
HT	40	R	27.50	10.00	10.00	47.50	27.50
		L	30.00	20.00	15.00	22.50	40.00
GT	84	R	27.38	7.14	7.14	46.43	32.14
		L	21.43	15.48	3.57	21.43	36.90
JT	39	R	43.59	10.26	15.38	41.03	15.38
		L	28.20	10.26	5.13	12.82	33.33
KT	40	R	27.50	2.50	5.00	45.00	35.00
		L	15.00	22.50	0.00	20.00	47.50
KZ	76	R	14.47	3.95	9.21	28.95	31.58
		L	18.42	10.53	3.95	6.58	30.26
Caucasoid groups							
AA	40	R	40.00	12.50	22.50	30.00	55.00
		L	37.50	22.50	10.00	27.50	52.50
BA	34	R	47.06	8.82	5.88	55.88	38.23
		L	50.00	8.82	0.00	23.53	44.12
FA	80	R	27.50	7.50	11.25	46.25	35.00
		L	28.75	12.50	6.25	23.75	53.75
KA	33	R	18.18	15.15	9.09	51.52	39.39
		L	18.18	18.18	3.03	12.12	60.61
TL	63	R	34.92	3.17	14.28	31.75	46.03
		L	38.09	9.52	6.35	15.87	50.79
DK	39	R	12.82	15.38	15.38	61.54	38.46
		L	28.20	20.51	12.82	43.59	64.10

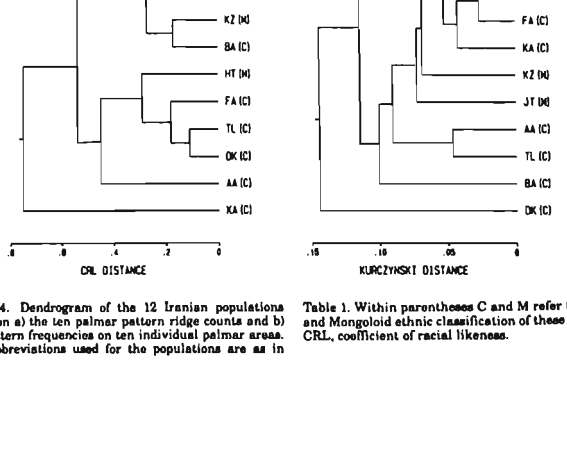

Fig. 4. Dendrogram of the 12 Iranian populations based on a) the ten palmar pattern ridge counts and b) the pattern frequencies on ten individual palmar areas. The abbreviations used for the populations are as in Table 1. Within parentheses C and M refer to Caucasoid and Mongoloid ethnic classification of these populations. CRL, coefficient of racial likeness.

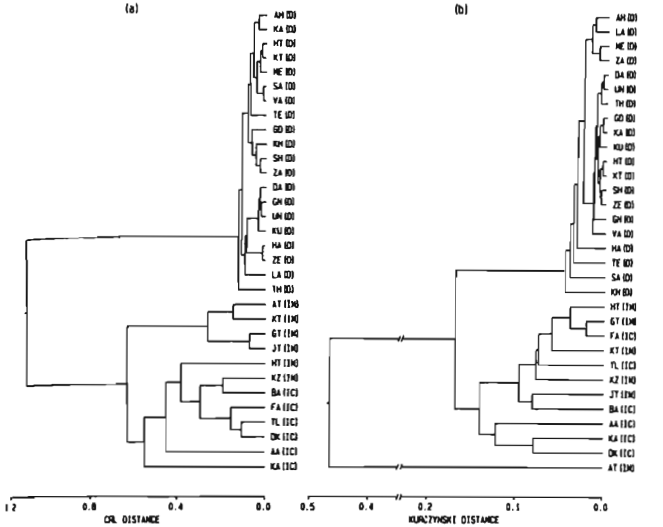

Fig. 5. Dendrogram of the 12 Iranian and 20 Dhangar caste populations based on a) the ten palmar pattern ridge counts and b) the pattern frequencies on ten individual palmar areas. The abbreviations used in this figure for the Dhangar castes are the same as designated in Malhotra (1979). Within parentheses, D, IC, and IM refer to Dhangar caste, Iranian Caucasoid, and Iranian Mongoloid, respectively. CRL, coefficient of racial likeness.

the palmar patterns not only among the major racial groups of man but also within geographical populations belonging to a single racial group.

DISCUSSION

The distributions of pattern ridge counts in different palmar configurational areas among the Iranian Mongoloids and Caucasoids are generally similar to the studies of Malhotra et al. (1983, 1986) and Borecki et al. (1985) among several population groups from the Indian subcontinent. Similarly, the pattern of variation in mean ridge counts and their variability between different palmar areas among the Iranian groups is in agreement with those among the Indian populations. Bias caused by sex dimorphism of palmar pattern sizes is not an issue here, since in all of these studies interpopulational differences were examined only with samples of males from each population.

However, it is noteworthy that in bimanual differences in mean ridge counts, the Iranian Mongoloid populations differ not only from the Iranian Caucasoids but also from the Indian groups in having larger patterns on the left palm compared to the right. This assumes further significance, since among a majority of the populations of different ethnic affiliations, including the Mongoloid populations, the patterns of the right-hand fingers are usually larger compared to those of the left (see, e.g., Holt, 1968; Jantz, 1979; Chakraborty et al., 1982).

Numerous earlier studies have established the existence of ethnic differences in the frequency of patterns in different palmar areas

(e.g., Cummins and Midlo, 1943; Plato et al., 1975; Garruto et al., 1979). In more recent interpopulational studies, palmar pattern frequencies either alone or in conjunction with other palmar and/or finger traits have been used (e.g., Chai, 1972; Heet and Keita, 1979; Rothhammer et al., 1979; Jantz and Chopra, 1983; Froehlich and Giles, 1981). However, it may be noted that a number of investigators have shown interethnic differences not only in the frequency occurrences of finger patterns but also in the size of finger patterns as determined by total or absolute finger ridge counts (e.g., Holt, 1968; Jantz, 1977).

Intuitively, it is therefore expected that interpopulational differences will not only be encountered in the palmar pattern frequencies, but, like finger patterns, palmar patterns may also depict significant ethnic differences in size as determined by ridge counts (PPRCs).

There is, of course, a basic difference between finger ridge counts and palmar pattern ridge counts as defined in this article. In defining finger ridge counts one does not exclude the zero counts for each finger, unlike the present methodology for palmar pattern ridge counts. Since in finger ridge count studies the frequency of individuals with zero counts on each digit is generally very small, total finger ridge count distribution (or mean) is not substantially affected by individuals with unpatterned finger ridge configurations. This is not the case with TPPRC, since the frequency of individuals with no pattern on any of the palmar areas is not small (e.g. Fig. 3 shows that in the pooled sample of the six Iranian Mongoloid groups, nearly 13% of individuals lack patterns on all five areas on both palms).

Nevertheless, we should mention that our approach in this article is not beyond caveat. The principal reason of excluding unpatterned areas in the analysis was to avoid statistical problems resulting from bimodality of distributions with inclusion of zero counts. Exclusion of these counts made the distributions unimodal, in general. However, some skewness still prevailed, particularly for individual palmar areas. Furthermore, different traits had different sample sizes that were substantially smaller than the number of individuals sampled. The reduction in sample sizes can be easily seen from a comparison of the number of individuals sampled with the proportion of pattern frequencies in each palmar area shown in Table 7. Therefore, we are inclined to suggest that the present methodology should be applied with large sample sizes to insure sufficient number of individuals with nonzero counts. In fact, we repeated the entire analysis with zero counts included. The results (not presented here) indicate that the interethnic separation of the population groups becomes blurred, since the palmar pattern frequencies do not always seem to cluster populations by their ethnic affiliation (see Fig. 4b and 5b). More theoretical work is needed to deal with this statistical problem of handling zero counts and palmar pattern sizes when patterns are actually observed on individual palms.

The present study shows that 1) there exists significant within and between population variation among the 12 Iranian populations in the PPRCs of all the configurational areas; 2) the pattern sizes in all the configurational areas among the Mongoloids are larger, often significantly, compared to the Caucasoids; and 3) the pattern of differentiation among the Iranian groups, or between Iranian groups and the Dhangar caste groups from India, correspond strongly with the known ethnohistory of these populations based on palmar pattern ridge counts rather than frequency of palmar patterns alone.

In conclusion, we emphasize that the present study demonstrates that the variation of palmar pattern ridge counts across different populations within an ethnic group as well as that among different ethnic groups may be a better indicator of interpopulational diversity than simple palmar pattern frequencies.

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