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SEXUAL DIMORPHISM IN MUZEINA BEDOUINS FROM SOUTH SINAI: MULTIVARIATE ANALYSIS ON DERMATOGLYPHIC TRAITS WITH ASYMMETRY AND DIVERSITY

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ABSTRACT

The objective of this study is to compare the pattern of sex differences between two different sets of dermatoglyphic traits: 22 quantitative and 40 indices of diversity and asymmetry through Multivariate analyses in Muzeina Bedouins with high inbreeding coefficient of 0.0908 (Kobyliansky and Hershkovitz 1997) from South Sinai. A degree of universality is observed in the "digital pattern size factor" indicate the genetic factor which has more influence on these variables than environmental factors in male and female. Similarity is also observed by the factors- "intra-individual diversity", "bilateral asymmetry" extracted from 40 traits which also suggests that a common biological validity exists in the underlying component structure. All variables (two groups) scattered into a number of small clusters are mainly categorized into three large and those are markedly similar between sexes. The above similarity was confirmed by the Mantel statistics- the Z values are within the level of non-significance, very good similarities in 22 (0.88) and good similarities in 40 (0.79) traits. Therefore, sex dimorphism is similar between two categories of dermatoglyphic traits which may be used for sex- discrimination in different ethnic populations.

***Keywords**: dermatoglyphics, multivariate analysis, Muzeina Bedouins, South Sinai*

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INTRODUCTION

Dermatoglyphic traits have traditionally been used in biological Anthropology to explore the affinities and differences among human groups since the pioneering work of Galton (1892). The assessment of biological relationships on different sets of variables is mainly based on sex relationships, bimanual asymmetry and intra-individual diversity. However, the result of sex–differences in dermatoglyphic traits in various populations still remains controversial (Cummins and Midlo 1961, Holt 1968; Schauman and Alter 1976; Loesch 1983, Meier 1990, Reddy and Reddy 2001, Karmakar et al.2001, 2002, 2005). The intrauterine environmental influences are more on the dermatoglyphic traits in males which were postulated by several authors (Jantz and Owsley 1977, Jantz and Webb 1980, Bailey et al., 1984, Kobyliansky and Livshits 1986). In the last few years, dermatoglyphic asymmetry and diversity have greatly broadened their scope and it deserves a special attention for several reasons (Holt 1960, Jantz 1975, Leguebe and Vrydagh 1979, 1981; Jantz and Webb 1982; Dittmar 1998, Micle and Kobyliansky 1986, 1991; Karev 1988, 1990; Karmakar et al 2001, 2003, 2005, 2008, 2009a, b, c; Sengupta and Karmakar 2006). Further, it is also known that dermatoglyphics plays an important role in Anthropo-genetics and evolutionary studies to characterize populations and to analyze the nature and origin of human variability (Meier 1980). In this context, the composite score of dermatoglyphic traits may be a more meaningful measure of developmental homeostasis than any single trait (Howells 1953, Potter et al 1968, Nakata et al 1974). The application of factor analysis is not new in dermatoglyphic variables (Knussman 1967, 1969; Roberts and Coope 1975, Froehlich 1976, Jantz and Owsley 1977, Reed et al 1978, Reed and Young 1979, Chopra 1979, Leguebe and Vrydagh 1981, Das Chaudhuri and Chopra 1983, Karmakar et al 2006, 2008, Karmakar and Kobyliansky 2009a). From this standpoint, to get a clear picture of this phenomenon, our comparative examination of biological validity of the underlying component structure of dermatoglyphic character is appropriate to compare between two Bedouin groups by principal component analysis.

Further, we have interesting results on the same issue in Indian populations (Karmakar et al 2001, 2003, 2005, 2006); Chuvashians (Karmakar et al 2008, 2009c) and Turkmenians (2009a, b) but, studies in the Bedouin populations are hardly available.

The present report of dermatoglyphics among the Bedouins was selected because, studies in Bedouins are hardly available. In this article, we therefore, explore the nature of sex dimorphism with respect to two different sets of dermatoglyphic traits (22 commonly used traits and 40 diversity and asymmetry traits) through Multivariate analyses which include- Cluster, and the Mantel test of matrix correlation in the Muzeina Bedouins of South Sinai peninsula.

MATERIALS AND METHODS

Sample and analyses of prints

For centuries the Muzeina tribe has inhabited the Sinai desert, which was especially occupied by the Bedouins and they originated mainly from the Saudi Arabian Peninsula (Kobyliansky and Hershkovitz 1997). The Muzeina tribe is characterized by strong biological isolation, rarely intermix and shows preference for first-cousin marriages. The frequency of such marriages is 15% and the inbreeding coefficient is 0.09. The sample contains the data of 380 individuals (281 men and 99 women). Finger and palmar prints were collected using the ink and roller method of Cummins & Midlo (1961). The prints were mostly evaluated following Cummins & Midlo (1961) and Holt (1968). Dermatoglyphic traits include total 22 quantitative traits- 12 finger and 10 palms); total 29 asymmetry traits (14 DA and 15 FA); and 11 diversity traits (Div) were considered in the present study. The dermatoglyphic variables are presented in Appendix 1 and the formulae for calculating various indices are set out in Appendix 2.

Statistical analyses

Principal component analysis (PCA): was performed using STATISTICA version 6 software (Stat Soft 2001). To avoid the problem of multiple comparisons, the redundancy of information, and repetition of measurement error, we performed principal component analysis using the original traits (Div, FA, and DA) regardless of the sex and the age of the individual, to capture as much common variation as possible. The eigenvalue >1 criterion was used to extract factors for the Div, FA and DA trait groups (Varimax rotation).

Cluster analysis: The phenotypic correlations between dermatoglyphic variables were determined in males and females separately. The obtained matrices of correlations were used to calculate the Euclidean distances between each pair of traits. These results were constructed by the complete linkage method and grouped into dendrograms, following Hartigan (1983).

Mantel test: The Mantel test statistic, Z, is used to measure the degree of difference in the relationships between two matrices. It takes two symmetric similarity/dissimilarity matrices and plots one matrix against the other (see Mantel 1967, Sokal 1979). The quantity of Z is obtained from the procedure of the corresponding elements of the two half-matrices, which are multiplied and summed up. The test criterion is:

$$Z = \Sigma \, Xij \; Yij,$$

where Xij and Yij are the off-diagonal elements of matrix X and Y.

Significance tests were carried out by comparing the observed, Z value with its per- mutational distribution. This distribution was obtained by comparing one matrix, say .X, with all the possible matrices, in which the order of the variables in the other matrix Y. has been permuted. If the two matrices show similar relationships, then Z should be the larger one. The MXCOM matrix comparison program was used for this analysis.

The data were processed at the Tel Aviv University Computer Center, Israel.

RESULTS

Principal component analysis

22 traits: The principal factors were obtained from the correlation matrices of quantitative dermatoglyphic traits (not shown in table). Four principal factors were extracted from 22 dermatoglyphic traits, namely total and absolute ridge counts; individual finger ridge counts; pattern intensity index (PII) and the palmar main lines index and its components (Table 1). These factors are presented in the order of their extraction which coincided with a decreasing order of the proportion of variance. The first factor "digital pattern size factor", which has high loadings for ridge counts of the ten fingers, as well as for the variables derived from these counts, namely total and the absolute ridge counts, and for the PII both in males and females. The second extracted factor "palmar main lines factor" with MLI. The third one extracted, describes palmar "a-b ridge count factor". The fourth factor has loadings higher than 0.250 for the same traits as the first factor of the finger ridge counts and may be called as "finger ridge count factor".

Table 1. Rotated factor loadings of 22 quantitative dermatoglyphic traits in Muzeina

Males (N = 281)					Females (N = 99)				
	Factor					Factor			
Trait	I	II	III	IV	**Trait**	I	II	III	IV
Absolute RC	0.94	–	–	–	Absolute RC	0.91	–	–	–
PII both h	0.92	–	–	–	PII both h	0.87	–	–	–
PII rh	0.87	–	–	–	Total RC	0.85	–	–	0.32
PII lh	0.87	–	–	–	PII rh	0.84	–	–	–
Total RC	0.84	–	–	0.45	Finger RC, IIIl	0.80	–	–	–
Finger RC, IVl	0.76	–	–	–	Finger RC, IIr	0.78	–	–	–
Finger RC, IIr	0.74	–	–	–	Finger RC, IVl	0.77	–	–	–
Finger RC, IIIl	0.73	–	–	–	Finger RC, IVr	0.77	–	–	–
Finger RC, IIIr	0.72	–	–	0.25	Finger RC, IIl	0.77	–	–	–
Finger RC, Vr	0.71	–	–	0.28	PII lh	0.76	–	–	–
Finger RC, Vl	0.71	–	–	0.30	Finger RC, IIIr	0.74	–	–	0.28
Finger RC, IVr	0.70	–	–	0.25	Finger RC, Vr	0.74	–	–	–
Finger RC, IIl	0.68	–	–	–	Finger RC, Vl	0.71	–	–	–
Finger RC, Il	0.38	–	–	0.75	Finger RC, Il	0.52	–	–	0.66
Finger RC, Ir	–	–	–	0.85	Finger RC, Ir	0.32	–	–	0.82
A-line, r	–	0.64	–0.43	–	D-line, r	–	0.74	–	–
a-b RC, l	–	–	0.78	–	D-line, l	–	0.73	–	–0.33
A-line, l	–	0.66	–0.38	–	a-b RC, l	–	–	–0.85	–
MLI	–	0.95	–	–	MLI	–	0.96	–	–
D-line, r	–	0.81	–	–	a-b RC, r	–	–0.33	–0.82	–
D-line, l	–	0.79	–	–	A-line, r	–	0.66	–	–
a-b RC, r	–	–	0.83	–	A-line, l	–	0.59	–	0.26
V.P.	8.29	3.23	1.92	2.00	V.P.	8.62	3.07	1.74	1.73
Cum.var.	37.66	52.32	61.44	70.13	Cum.var.	39.18	53.13	61.02	68.89

[1] Loading values below 0.25 are omitted. The V.P. is the variance explained by each factor. Cum. var. is the cumulative proportion of explained variance.

40 *traits*: In the second principal component analysis, 40 dermatoglyphic variables were used including indices of intra-individual diversity (Div) and two types of asymmetry-directional (DA) and fluctuating (FA). Ten principal factors were extracted, the order of their extraction coincided with the decreasing order of the portion of the total variance accounted for by each factor (Tables 2–3). The first two principal factors which represent mainly the intra-individual diversity of finger ridge counts may be called as “intra-individual diversity factor”. In each sex the first extracted factor has high loadings for the ten indices of intra-individual diversity. In both sexes the first factor has also high loadings

Table 2. Rotated factor loadings of 40 variables of diversity and asymmetry in males

	Factors									
Trait	I	II	III	IV	V	VI	VII	VIII	IX	X
Div IX	0.96	–	–	–	–	–	–	–	–	–
Div X	0.96	—	–	–	–	–	–	–	–	–
Div VI	0.95	–	–	–	–	–	–	–	–	–
Div III	0.92	–	–	–	–	–	–	–	–	–
Div VIII	0.83	0.41	–	–	–	–	–	–	–	–
Div VII	0.83	–0.48	–	–	–	–	–	–	–	–
Div I	0.82	–0.47	–	–	–	–	–	–	–	–
Div II	0.82	0.40	–	–	–	–	–	–	–	–
Div IV	0.81	–0.45	–	–	–	–	–	–	–	–
Div V	0.81	0.39	–	–	–	–	–	–	–	–
FA XIII	0.47	–	–	–	–	0.50	–	–	–	–
FA XII	0.39	–	–	–	–	0.53	–	–	–	–
FA XVI	0.39	–	–	–	–	0.72	–	–	–	–
FA IV	0.28	–	–	–	–	0.77	–	–	–	–
DA XIV	–	0.50	–	–	–	–	–	–	–	–
FA XI	–	–	–	–	–0.27	–	0.26	–	–0.44	0.25
Div XI	–	–	–	–	–	–	0.73	–	–	–
FA X	–	–	–	–	–	–	0.31	–	–	–
DA IV	–	–	–	0.88	–	–	–	–	–	–
FA VII	–	–	–	–	–	–	–	0.67	–	–
DA XI	–	–	–	0.26	–	–	–	–	–	–
Dam XV	–	–	–	–	–	–	–	–	0.68	–
DA X	–	–	–	–	–	–	–	–0.41	0.25	0.45
DA VI	–	0.78	–0.48	–	–	–	–	–	–	–
FA XV	–	–	–	–	–	–	–	–	0.71	–
DA III	–	–	–	–	–0.86	–	–	–	–	–
FA II	–	–	–	–	–	–	0.76	–	–	–
FA XIV	–	–	–	–	–	0.49	–	–	–	–
DA IX	–	–	–	–	0.85	–	–	–	–	–
DA XII	–	–	–	0.54	–	0.38	–	–	–	–
DA V	–	0.95	–	–	–	–	–	–	–	–
DA I	–	0.94	–	–	–	–	–	–	–	–
FA IX	–	–	–	–	–	–	–	–	–	0.61
DA II	–	–	–	0.26	–	–	0.39	–	–	–
DA VII	–	–	–	–	–	–	–	–0.73	–	–
FA III	–	–	–	–	–	–	–	–	–	–
FA I	–	–	0.94	–	–	–	–	–	–	–
DA XIII	–	–0.32	–	0.63	–	–	–	–	–	–
FA V	–	–0.05	0.94	–	–	–	–	–	–	–
FA VI	–0.29	–0.35	0.77	–	–	–	–	–	–	–
V.P.	8.54	4.21	2.92	2.23	1.65	2.45	1.61	1.43	1.48	1.53
Cum.var.	21.36	31.88	39.18	44.79	48.88	55.01	59.04	62.61	66.30	70.12

[1] Loading values below 0.25 are omitted. The V.P. is the variance explained by each factor. Cum. var. is the cumulative proportion of explained variance.

Table 3. Rotated factor loadings of 40 variables of diversity and asymmetry in females

	Factors									
Trait	I	II	III	IV	V	VI	VII	VIII	IX	X
Div VI	0.99	–	–	–	–	–	–	–	–	–
Div IX	0.99	–	–	–	–	–	–	–	–	–
Div III	0.98	–	–	–	–	–	–	–	–	–
Div X	0.95	–	–	–	–	–	–	–	–	–
Div V	0.91	–0.28	–	–	–	–	–	–	–	–
Div IV	0.90	0.27	–	–	–	–	–	–	–	–
Div II	0.90	–0.33	–	–	–	–	–	–	–	–
Div I	0.90	0.35	–	–	–	–	–	–	–	–
Div VIII	0.90	–0.34	–	–	–	–	–	–	–	–
Div VII	0.89	0.36	–	–	–	–	–	–	–	–
FA XIII	0.58	–	–	0.30	–0.43	0.34	–	–	–	–0.29
FA X	0.49	–	–	0.43	–	–	–	–	–	–0.51
FA XVI	0.47	–	–0.31	–	–0.56	–	–0.30	–	–	–
FIAs XI	0.42	–	–0.28	–	–	0.49	0.25	–	–	–
DA IV	–	–	–	0.41	–0.26	–	0.30	–	–	0.59
FA XII	–	–	–	–0.25	–0.33	0.67	–	–	–	–
DA XIV	–	–0.72	–	–	–	–	–	–	–	–
DA XII	–	–	–	–	–0.27	–	0.40	–	0.67	0.29
FA IV	–	–	–	–	–0.87	–	–	–	–	–
DA VI	–	–0.76	0.56	–	–	–	–	–	–	–
DA III	–	–	–	–	–	–	–	0.86	–	–
DA XIII	–	–	–	–	–	–0.37	–	–	–	0.86
FA XIV	–	–	–0.44	–	–	–	–0.37	–	–	0.37
DA IX	–	–	–	–	0.46	–	–	–0.64	–	–
DA XV	–	–	–	–	–	–	–	–	–0.69	–
Div XI	–	–	–	0.26	–	0.62	–	–	–	–
DA II	–	0.33	–	–	–	–	–	–	0.66	–
DA X	–	–	–	0.88	–	–	–	–	–	–
DA I	–	–0.94	–	–	–	–	–	–	–	–
DA VII	–	–	–	–	–	–	0.61	–	–	–
DA V	–	–0.94	–	–	–	–	–	–	–	–
FA II	–	–	–	–	–	0.67	–	–	–	–
FA IX	–	–	–0.56	–	–0.44	–	0.33	–	–	–
DA XI	–	–	–	–	–	0.67	0.49	–	–	–0.25
FA XV	–	–	–	–0.32	–	0.34	–0.37	–	–	–
FA VII	–	–	–	–	–	–	–0.35	–0.58	–	–
FAsIII	–	–	–	0.27	–0.57	–	–	–0.31	–	–
FA V	–	–	–0.87	–	–	–	–	–	–	–
FA VI	–	0.35	–0.80	–	–	–	–	–	–	–
FA I	–	–	–0.87	–	–	–	–	–	–	–
V.P.	10.20	4.01	3.52	1.84	2.66	2.56	1.87	1.88	1.75	2.02
Cum. var.	25.50	35.53	44.33	48.93	55.58	61.98	66.66	71.37	75.74	80.79

[1] Loading values below 0.25 are omitted. The V.P. is the variance explained by each factor. Cum. var. is the cumulative proportion of explained variance.

for the indices of fluctuating asymmetry of ridge counts on four fingers. The second factor has high loadings for the last six indices of intra-individual diversity, related only to the ridge counts of the five fingers of each hand and representing some indices of directional asymmetry. The remaining third to tenth, all factors has loadings which are representing only directional (DA) and fluctuating asymmetry (FA) but, no one may be called separately as DA or FA factor in both sexes and thus may be called as the "bilateral asymmetry factor".. However, some minor differences existing in the two sexes occur in the extraction order among these factors, which cannot be compared properly.

Cluster analysis*:* The cluster trees have been drawn based on the correlation matrices of 22 quantitative dermatoglyphic traits, and 40 dermatoglyphic traits of intra-individual diversity and asymmetry in males and females (Fig. 1a, 1b, and Fig. 2a, 2b).

22 traits: The dendrograms, based on 22 quantitative dermatoglyphic traits in males and females, are presented in Figures 1a and 1b. Clearly, the cluster trees represent three main clusters for both sexes. Of the three, the first cluster is the broadest one and comprises variables of the ridge counts of individual fingers; total (TFRC) and absolute (AFRC) ridge counts and the pattern intensity index (PII). The PII counts are aggregated at the end of the first cluster in the area connecting the second cluster, and they appear in a separate component. The second cluster includes the palmar a–b ridge counts. The third cluster comprises the main line index (MLI) and its components. These results are very similar between males and females. *40 traits:* The dendrograms based on 38 dermatoglyphic traits consist of intra-individual diversity, as well as directional and fluctuating asymmetry; they are presented in Figures 2a and 2b for males and females, respectively. The cluster trees can be classified into three main clusters. The first_cluster comprises 11 intra-individual diversity indices of the finger ridge counts that they are joined by some other measures of FA indices. The second cluster is mainly aggregated by the indices of fluctuating asymmetry as well as directional asymmetry. The third cluster contains the variables of directional asymmetry and some indices of fluctuating asymmetry. All the variables form a number of small sub-clusters under the broad clusters and in general, these variables are scattered into a number of small clusters. The dendrograms between males and females are markedly similar; only a small number of rearrangements have occurred.

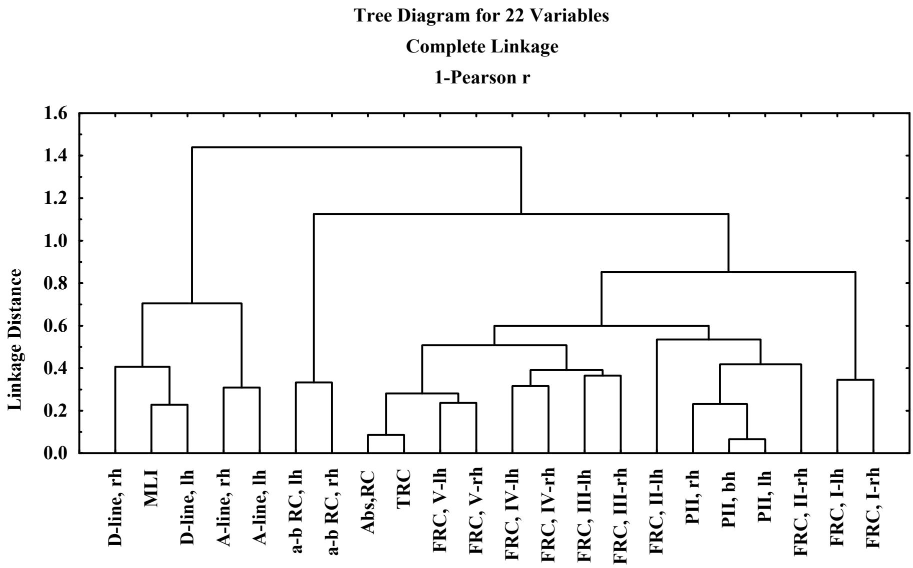

Figure 1a. Muzeina Beduins (Males, N = 281); 22 quantitative traits; case-wise Mean Substitution.

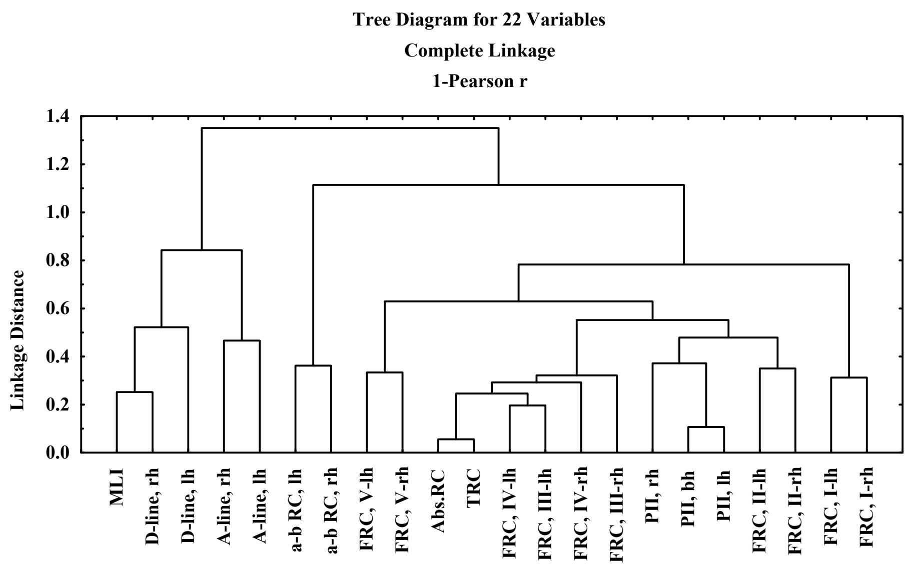

Figure 1b. Muzeina Beduins (Females, N = 99); 22 quantitative traits; case-wise Mean Substitution.

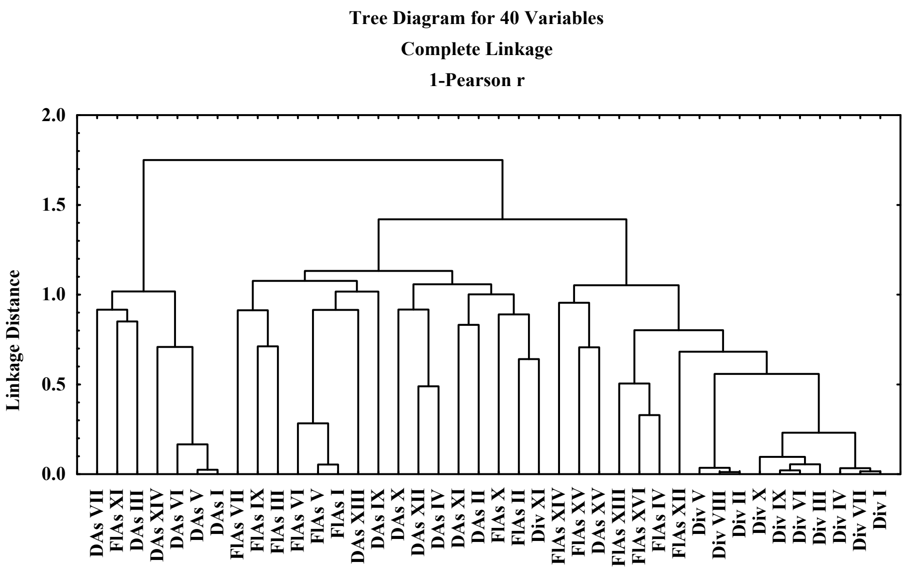

Figure 2a. Muzeina Beduins (Males, N = 281); 40 diversity and asymmetry traits; case-wise Mean Substitution**.** (DAs = Directional asymmetry, FLAs = Fluctuating asymmetry).

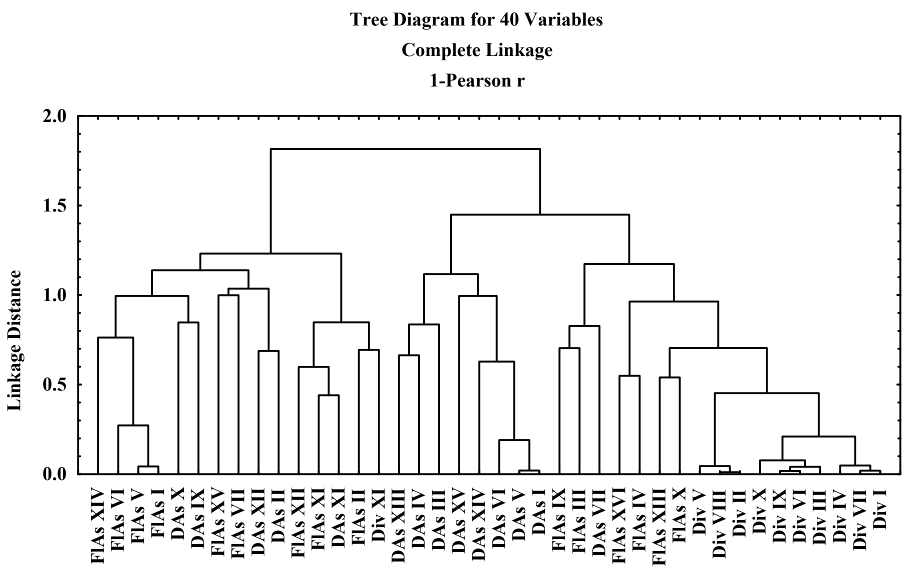

Figure 2b. Muzeina Bedouins (Females, N=99); 40 diversity and asymmetry traits; case-wise Mean Substitution. (DAs = Directional asymmetry, FLAs = Fluctuating asymmetry).

The Mantel test of matrix correlations

With the aim of comparing these two categories of variables with respect to male vs. female, we performed the Mantel test of matrix correlations for significance tests within the Muzeina population. The two groups of variables, which proved to be almost similar between males and females, were confirmed by the similarity/correspondence test of the Mantel statistic Matrix correlation r = 0.78 (Z). The values of Z are within the level of non-significance, i.e., very good similarities in 22 (0.88) and good similarities in 40 (0.79) traits. The levels of similarity are: $0.9 \leq r$ (very good) and $0.8 < r \leq 0.9$ (good).

DISCUSSION

The results which were presented in the preceding pages will be discussed under the following headlines:

Principal component analysis

22 traits: Factor 1 – "digital pattern size factor", Factor 2 – "palmar main lines factor", Factor 3 – "a–b ridge count factor" and Factor 4 – "finger pattern intensity factor" extracted from 22 quantitative variables in both sexes. The first three factors are comparable with the earlier studies in Melanesian populations (Froehlich and Giles1981); in the German population (Chopra 1979); in the English population (Roberts and Coope 1975); in the Taimir aborigine (Galaktinov et al. 1982); in the Indian population (Das Chaudhuri and Chopra 1983, Krishnan and Reddy 1992, Karmakar et al. 2006, 2008, 2009; Sengupta and Karmakar 2006); and in the Jewish population (Micle and Kobyliansky 1986, 1991). The fourth factor is similar with earlier studies (Micle and Kobyliansky 1986, 1991, Karmakar et al. 2002). Especially, factor 1 (digital pattern size factor) is remarkable, due to its degree of universality observed in different racial/geographical and sex groups, which supports the following hypothesis: (i) the general size of the finger pattern (Chopra 1979) indicates that no separate complexes are responsible for individual fingers. (ii) Each finger is a discrete part of a digital complex comprising ten fingers and not a separate unit acted on independently by the genes involved (Butler 1963). (iii) This theory is also supported by Roberts and Coope (1975) and Jantz and Owsley (1977) in their studies of factor analysis on dermatoglyphic data.(iv) The genetic factor possibly has more influence on these variables than environmental factors in male and female indicated by Jantz (1977) in his study between American and African Negro samples.

40 traits: Among the factors describing the variability of 40 indices of diversity and asymmetry, mainly two factors – "intra-individual diversity" and "bilateral asymmetry" are revealed prominent in both sexes out of extracted 10 factors (Tables 2–3).

In view of hardly available such study (on diversity and asymmetry) in the literature on dermatoglyphic component structure we cannot compare in detail. However, we found that these two factors extracted from 40 dermatoglyphic traits in the Bedouins is fully corroborate with our earlier studies on the same issue in five Indian populations (Karmakar et al. 2001), Israeli Jews (Micle and Kobyliansky (1986, 1991), Chuvashians of Russia (Karmakar et al. 2008), the Turkmenian population (Karmakar et al. 2009). In this respect, we can explain that there may be a degree of universality in the structure of the components, which exhibits a common similarity in both sexes among different racial/geographical populations along with some rearrangements of traits (indices of directional and fluctuating asymmetry) associations. However, confirmation needs further studies in different populations.

Cluster analysis: The similarity of the dermatoglyphic variables in males and females between the two groups is well reflected by the cluster analysis of the Muzeina Bedouins (Figs. 1a, 1b, 2a, and 2b).). Three main clusters were obtained from each of the two categories of variables that are exactly similar between the two sexes, although a number of rearrangements took place in the variables associated with these clusters. With the same objective and based on the same variables the dendrograms obtained by Micle and Kobyliansky (1991) in the Jewish populations, Karmakar et al. (2003) in five Indian populations and in the Chuvashian populations (Karmakar et al. 2008). Our present results are in agreement with these results and may suggest a common genetic background and the possible influence of environmental factors on the realization of sexual dimorphism.

The Mantel test of matrix correlations

The present results between sexes in Muzeina Bedouins are with good similarities in two sets of dermatoglyphic traits and were fully corroborated with the earlier findings in different populations: in North African Jews Kobyliansky and Micle (1988); in Israeli populations, Micle and Kobyliansky (1991); Karmakar et al. (2003) among five different Indian populations; in the Chuvashian population Karmakar et al. (2008, 2009c); in the Turkmenian population Karmakar et al. (2009a,b).

CONCLUSION

A degree of similarities is observed in the factors – "digital pattern size factor", "intra-individual diversity", "bilateral asymmetry" etc., which possibly indicates that the genetic factor has more influence on these variables than environmental factors and a biological validity exists in the underlying component structure between sexes in Muzeina Bedouins like other populations. The results of cluster and the Mantel test strongly suggest that the two different sets of dermatoglyphic traits may be used for sex-discrimination in different populations.

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Appendix 1: List of the utilized traits and indices

22 quantitative traits	**13 Directional Asymmetry (DAs) traits**
Finger RC, I r	DA I = Div II – Div I
Finger RC, II r	DA II = PII, rh – lh
Finger RC, III r	DA III = a-b RC, r – l
Finger RC, IV r	DA IV = hRC, rh – lh
Finger RC, V r	DA V = S^2, rh – lh
Finger RC, I l	DA VI = Div VIII – Div VII
Finger RC, II l	DA VII = atd angle, r – l
Finger RC, III l	DA X = fRC, Vr – Vl
Finger RC, IV 1	DA XI = fRC, IVr – IVl
Finger RC, V 1	DA XII = fRC, IIIr – IIIl
Total RC (TRC)	DA XIII = fRC, IIr – IIl
AbsRC	DA XIV = fRC, Ir – Il
PII, lh	DA XV = MLI, rh – lh
PII, rh	**14 Fluctuating Asymmetry (FA) traits**
PII, both h	FA I = [Div I – Div II]
a-b RC, rh	FA II = PII, [rh – lh]
a-b RC, lh	FA III = a-b, RC, [rh – lh]
A-line exit, l	FA IV = hRC, [rh – lh]
A-line exit, r	FA V = [Div V – Div IV]
D-line exit, l	FA VI = [Div VIII – Div VII]
D-line exit, r	FA VII = atd angle, [r – l]
MLI	FA X = fRC, [Vr – Vl]
38 traits (diversity and asymmetry):	FA XI = fRC, [IVr – IVl]
11 Diversity traits (Div)	FA XII = fRC, [IIIr – IIIl]
Div I = max – min fRC (lh)	FA XIII = fRC, [IIr – IIl]
Div II = max – min fRC (rh)	FA XIV = fRC, [Ir – Il]
Div III = max – min fRC (both h)	FA XV = MLI, [rh – lh]
Div IV = S^2 for lh, (or S^2L)	FA XVI = A1, asymmetry index
Div V = S^2 for rh, (or S^2R)	
Div VI = S2 (both h)	DA VIII – IX and FAVIII – IX, based on a-b dist, a-b ridge breadth were excluded from the analysis. Numbering of the traits remain as in our other publications, for simplification of comparison with our previous data.
Div VII = IIDL (for lh)	
Div VIII = IIDR (for rh)	
Div IX = S $\sqrt{10}$, (both h)	
Div X = S $\sqrt{5}$, (both h)	
Div XI = Shannon's index	

Abbreviations: RC = ridge count; r = right; l = left; h = hand; PII – Pattern Intensity Index; MLI = main line index; Div I to Div XI = indices of intra-individual diversity of finger ridge counts; DA I to DA XV = indices of directional asymmetry; FA I to FA XVI = indices of fluctuating asymmetry.

Appendix 2: *Formulae for some indices of dermatoglyphic diversity and asymmetry:*

The directional asymmetry (DA) was computed by the following equation:

$$DAij = X_{iR} - X_{iL}.$$

The fluctuating asymmetry (FA) was computed by using the absolute differences between the bilateral measurements. The distributions of the non-absolute differences for each individual were corrected (Livshits et al., 1988) to avoid additional influences (scaling effects) like size of the trait or directional asymmetry, yielding the following equation for computing FA:

$$FA_{ij} = \left| (X_{iR} - X_{iL}) - 1/n \sum_{i=1}^{n} [(X_{iR} - X_{iL}) \right|$$

Where, xi = trait (x) of individual (i); R, L = right and left, n = size of the sample and FA_{ij} is the value of FA of trait (j) in the I th individual.

Div I, Div II, Div III. Maximal minus minimal finger ridge counts in the five left (Div I), five right (Div II), or in the ten finger ridge counts (Div III). Div IV, Div V = $\sum_{i=1}^{5} q_i^2 - Q^2/5$, for the left (Div IV, S^2L), or right fingers (Div V, S^2R); Div VI, $S^2 = \sum_{i=1}^{10} q_i^2 - Q^2/10$; Div VII, Div VIII = $\sqrt{\sum_{i=1}^{5} q_i^2 - Q^2/5}$, for the left (Div VII, IIDL), or right finger (Div VIII, IIDR); Div IX, $S\sqrt{10} = \sqrt{\sum_{i=1}^{10} (q_i^2 - Q^2/10)/10}$; Div X, $S\sqrt{5} = \sqrt{\sum_{i=1}^{5} (k_i^2 - Q^2/5)/5}$;

In these formulae, q_i is the ridge count for the i^{th} finger, Q is the sum of the five finger ridge counts of a hand (Div IV, V, VII, VIII) or of all the ten fingers (Div VI, IX, X), and k is the sum of ridge counts of the i^{th} pairs of homologous right and left fingers.

Div.XI. Shannon's index, D = $-\sum_{i=1}^{4} P_i \log P_i$ where P_i is the frequency of each of the four basic finger pattern types on the ten fingers; Abs XVI, AI = $\sqrt{\sum_{i=1}^{5} (R_i - L_i)^2}$, where R_i and L_i are the ridge counts for the i^{th} finger of the right and left hand.