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The method of pattern combination analysis in dermatoglyphics: I. Diversity and sex differences among the regional populations of the Yanadi

A method of pattern combination analysis (PCA) is described. It consists of three categories: Pattern combination types (PCT), Triradial pattern combination types (PCT-tr) and Pattern combination ratios (PCR) with specific reference to ten digits and its several indices. The method has been used to investigate its validity in discriminating subdivided populations among the Yanadi tribe. The results show significant differences and a few unique pattern combinations in monomorphic and trimorphic frequencies and also in triradial pattern combination types, especially observed in IY population. Between the five Yanadi populations, the results obtained in all the categories of pattern combinations, in pattern combination indices, were in agreement with respect to the population structure variables of the five populations. The results also show clear sex differences especially observed in triradial pattern combination types (PCT-tr) and absence of tetramorphic patterns and ratios among females. This method can be further used for studying inheritance of the PCA, inbreeding effects and other issues of statistical distributional pattern and other theoretical and empirical aspects of anthropological genetics.

Key words: Pattern combination types (PCT), Triradial pattern combination types (PCT-tr.), Pattern combination ratios (PCR). Pattern diversity index (PDI), Pattern combination Indice.

The concept of pattern combination (treating all the digits together) can be traced by the "unimanual and bimanual" method proposed by Poll (1928). Volotzkoy had considered individuals with only one common pattern in all the ten fingers (e.g., either all loops or whorls) and defined as "Monomorphic" individuals (Cummins and Midlo, 1961). Further development of pattern combinations using information theory was proposed by Quastler (1953). And Lu (1968) has applied both information and discriminant analyses to the pattern combination types in all ten fingers for the identification of mental status categories including mongolism. By identification of unique pattern combinations in the form of (dictionary of) digital-coded sequences, Lu (1968) was able to show that about 45.4% of the data contained unique pattern types. A similar method of digital coded dictionary of total finger pattern types based on topological principles was proposed by Penrose and Loesch (1969, 1970) and Loesch (1975). By computing ulnar and radial components separately for each digital coded total finger pattern types among three mental status groups, Loesch (1975) found low pattern variability for Mongols. Followng Lu (1968), Micle and Kobyliansky (1988) extended the application of Shanon's entropy measure to the several proportions or ratios of relative frequency of pattern combionation types to study intra-individual diversity among Israeli Jews and found significant sex differences with respect to four pattern type combinations. But, Karov (1990) by following Micle and Kobyliansky's method has not found significant sex differences in intraindividual diversity among the Bulgarian sample.

A formal development of both pattern combination types and its ratios developed b Vasulu et al. (1991) found to be applicable to intra and inter individual (population) variation to discriminate among normal and nonnormal populations. They observed greater variability and significant differences between three nonnormal and among three endogamous populations. But its wide applicability in relation to other bioloical measures and other issues of anthropological genetics need to be confirmed.

In the present study the method of pattern combination analysis and its extension to topological landmarks of triradial numbers and pattern intensities are described and applied to finger dermatoglyphics data in a tribal population, the Yanadi, with an objective to test the validity and utility of pattern combination analysis, especially (a) investigating dermatoglyphic diversity and sex differences, and (b) in relation to population structure variables so as to infer microevolutionary phenomenon between subdivided population of the tribe.

Population

The Yanadis is an aboriginal tribe mostly distributed in southeastern parts of Andhra Pradsh, India. They are widely distributed in different regions of coastal, island, plateau and hillforest regions and differ in their subsistence pattern and other associated cultural variables. For example, on the islands of Pulikate lake, the tribe is in hunting-gathering-incipient agriculture stage; in plateau region they are mostly casual and agricultural labourer, and in hillforest region they are gatherers and occasional agricultural labourers, except for one or two settled agriculturalists. The ethnographic information suggests an historical migration from their original abode to different regions for survivasl reasons, in the past, possibly more than 15 decades ago, as that could be traced from records.

A detailed demographic information on 13 Yanadi settlements in different regions, suggests that the Yanadi live in settlements of varying size of a few huts to 100 households, which is associated with different subsistence levels and other cutural variables in different regions. A detailed analysis of the population structure, endogamy and exogamy, surname analysis, inbreeding levels reveal that the Yanadi form regional breeding populations localized among a few settlements in a region. The breeding isolation is prompted by geographical barriers, spatial distribution, differences in subsistence pattern etc., (Vasulu, 1989). A detailed study among the 13 settlements in coastal, plateau, hillforest and coastal islands in different regions suggest that they differ in their subsistence pattern and other associated cultural traits and also form local or regional breeding populations. The five breeding populations thus identified are; CY: Challa Yanadi, IY: Insular Yanadi, P1: and P2: Plateau Yanadis and HF: hillforest Yanadi. Detailed genealogical and demographic survey shows that these five breeding populations differ in their populations structure variable. For example, CY and IY are two separate endogamous populations, whereas, P1, HF and P2 reflect low levels of mate exchange. Details of populations structure variables of the five breeding populations are given in Table 1. Further details on the breeding isolation have been described earlier (Vasulu, 1989).

Based on the information of varying degrees of differences in population structure variables, the following specifc hypotheses may be raised. Corresponding to the pattern observed in endogamy and admixture rate (Table 1), it is expected that both CY and IY should reflect greater dermatoglyphic variation than P1, HF and P2. One more objective of the study is to verify whether the Yanadi also show sex differences in dermatoglyphics as was found by an earlier study (Micle and Kobyliansky, 1988). And if so, what is the extent of these sex differencs? Does it vary among the regional populations of the Yanadi? Can this be related to population structure variables of migration and marriage pattern? These are investigated in two separate parts, in the present study and the following paper (Vasulu, 1997a).

The method of pattern combination analysis

Pattern combination

Consider the four basic (finger or toe) dermatoglyphic patterns: Arch(A), Ulnar loop (UL), Radial loop (RL) and Whorl (W). In general an individual (population) can exhibit either one or two or three or all the four pattern types in all the (ten) digits. The occurrence of any one pattern common in all the digits was already referred as "Monomorphic patterns" by Volotzkoy (Cummins and Midlo, 1961). The definition of Volotzkoy's monomorphic patterns can be extended to two, three and four pattern combinations. For example, an individual (populations) exhibiting just two patterns on all the (ten) digits can be described as "Dimorphic patterns". Likewise, the occurrence of three and four pattern combinations can be described as "Trimorphic' (- three pattern combinations -) and "Tetramorphic" (- four pattern combinations -) respectively. In general, the above pattern combinations of "Dimorphic", "Trimorphic" and "Tetramorphic patterns" can be referred by a common terminology "Polymorphic pattern-combinations".

1. Pattern combination types (PCT):

An individual can be monomorphic for any of the four (4_C1) patterns (A, UL, RL, W), but the most frequently occurring monomorphic patterns are limited to UL or W (and very rarely A).

There are 6 possible combinations of "Dimorphic patterns" (4_C2) that can occur in an individual (population). viz.,

1. UL-W, 2. UL-RL, 3. UL-A, 4.W-RL, 5. W-A, 6. A-RL

The first three dimorphic patterns occur more frequently and the last three are very rare.

In case of "Trimorphic patterns" there are four porrible types (4_C3). viz.,

1. UL-W-RL, 2. UL-W-A, 3. UL-RL-A, 4. W-RL-A

Of the four, the first two are most frequent.

But as for as all the four patterns (Tetramorphic patterns), it can occur together (in an individual or on ten digits) in one possible combination (4_C4) only, viz.,

UL-W-RL-A

Altogether there will be 15 PCT for four categories.

2. Triradial pattern combination types or Pattern combination types with number or triradii (PCT-tr)

Even the qualitative method of pattern vombination types can also be treated as "semi-quantitative" by considering the number of triradii involved in each of the PCT, which in a way can be related to Penrose and Loesch's method of identification of dermatoglyphic patterns on the basis of topological principles. In such case, the four PCT can be classified into the following five categories:

1. PCT with zero triradius or zero-triradial pattern combination (PCT-0tr.),
2. PCT with one triradius or mono-triradial pattern combination (PCT-1tr.),
3. PCT with two triradii or di-triradial pattern combination (PCT-2tr.),
4. PCT with three triradii or tri-triradial pattern combination (PCT-3tr.) and
5. PCT with four triradii or tetra-triradial pattern combinations (PCT-4tr.).

The correspondence between PCT-tr. and PCT are:

PCT with 0 triradius: Monomorphic A
PCT with 1 triradius: Monomorphic UL and Dimorphic UL-A, RL-A
PCT with 2 triradii: Monomorphic W; DImorphic UL-RL, W-A, and trimorphic UL-RL-A
PCT with 3 triradii: Dimorphic UL-W, RL-W and trimorphic UL-W-A, RL-W-A
PCT with 4 triradii: Trimorphic UL-RL-W and tetramorphic UL-RL-W-A

Of all the five PCT-tr, PCT-0tr. is very rare whereas, PCT-3tr. is most frequent. In addition to the above cases, some times very rare pattern combinations involving five patterns can occur due to composite pattern types involving both whorl and loop in one or more digits. In such a case, there will be "pentamorphic or (hexmorphic)" and PCT-5tr. (or PCT-6tr.) categories and etc.

3. Pattern combination ratios (PCR):

The frequency of each of the above 15 pattern combinations on all the (ten) digits (PCT) occur in different ratios of its relative frequencies. To be specific, the four monomorphic patterns can occur only once. But each of the 6 dimorphic patterns can occur on all the (ten) digits in as many as 9 different ratios or (n-1) ways or proportions where 'n' is the number of digits. The "dimorphic ratios" are:

1:9, 2:8, 3:7, 4:6, 5:5, 6:4, 7:3, 8,2, 9:1

In case of trimorphic patterns, each of the four can occur on all the digits in 36 different ratios. The "Trimorphic ratios" are:

$$\{\sum_{n=3}^{10} (n-2)\}$$

where 'n' is the number of possible ways of obtaining two pattern combinations for every given 8 ways of the third pattern. For example, it can occur 1UL-1RL-8W or 7UL-2W-1A etc.,

But the tetramorphic patterns can occur in 84 different ratios (e.g., 6UL-2W-1RL-1A). All the 'Tetramorphic ratios' are

$$\sum_{n=3}^{10} \sum_{k=3}^{10} (n-K)$$

where, 'n' is the number of possible ways of obtaining three patterns for every 'k' ways of the fourth pattern. However, in practice only a few tetramorphic ratios are important, many of them are rare or practically absent.

TABLE 1- Sample size for dermatoglyphics and population structure variables of breeding isolation among the Yanadi.

Variable		Yanadi population				
		CY	IY	P1	HF	P2
Dermatoglyphics						
Sample size	Male	40	68	93	156	171
	Female	48	63	48	79	166
	Total	88	131	141	235	337
Admixture rate		0	0	1.2+0.8	2.4+0.8	0.3+0.3
Mean Marital Distance		10.86	12.02	15.81	24.79	18.20
Surname migration index		17.0	2.5	38.3	11.8	24.8
Inbreeding coefficient		0.026	0.043	0.029	0.038	0.041
Crow's Index I		0.904	0.753	0.258	0.567	0.443

TABLE 2 - Shanon diversity measure (SDM), pattern types and ratios

SDM Rank	SDM Value	FPC no.	FPC ratio	Types of finger pattern combination
Monomorphic				
1	0.0000	1	10:0	Four monomorphic patterns W, UL, A, RL
Dimorphic				
2	0.3251	2	9:1	Six types of dimorphic patt-
3	0.5004	2	8:2	erns :
4	0.6109	2	7:3	UL-W UL-RL UL-A
6	0.6730	2	6:4	W-RL W-A A-RL
7	0.6931	2	5:5	and 9 possible ratios of each
Trimorphic				
5	0.6390	3	8:1:1	Four types of trimorphic
8	0.8018	3	7:2:1	patterns
9	0.8979	3	6:3:1	UL-W-RL UL-W-A
11	0.9433	3	5:4:1	UL-RL-A W-RL-A
12	0.9503	3	6:2:2	and 36 possible ratios of each
13	1.0297	3	5:3:2	
14	1.0549	3	4:4:2	
15	1.0889	3	4:3:3	
Tetramorphic				
10	0.9404	4	7:1:1:1	One type of tetramorphic
16	1.0889	4	6:2:1:1	pattern W-UL-RL-A and 84
17	1.1683	4	5:3:1:1	possible ratios
18	1.1935	4	4:4:1:1	
19	1.2206	4	5:2:2:1	
20	1.2798	4	4:3:2:1	
21	1.3138	4	3:3:3:1	
22	1.3322	4	4:2:2:2	
23	1.3662	4	3:3:2:2	

TABLE 3 - Per cent frequencies of different types of finger pattern combinations (FPC) among the Yanadi.

FPC Type	Male					Female				
	CY	IY	P1	HF	P2	CY	IY	P1	HF	P2
n	39	67	93	151	171	47	63	49	83	165
Monomorphic										
W	5.1	7.5	1.1	7.3	8.8	0.0	7.9	2.0	6.0	6.7
UL	7.7	0.0	4.3	5.3	4.1	2.1	1.6	6.1	6.0	3.6
Total	12.8	7.5	5.4	12.6	12.9	2.1	9.5	8.2	12.1	10.3
Dimorphic										
UL-W	71.8	62.7	67.7	66.2	67.3	74.5	60.3	73.5	66.3	66.1
UL-RL	5.1	0.0	3.2	2.0	0.6	2.1	1.6	2.0	1.2	2.4
UL-A	5.1	2.9	6.4	1.3	1.2**	6.4	9.5	6.1	6.0	3.0
Total	82.1	65.7	77.4	69.5	69.0	83.0	71.4	81.6	73.5	71.5
Trimorphic										
W-UL-RL	0.0	17.9	12.9	10.0	8.2*	8.5	6.4	6.1	3.6	6.1
W-UL-A	5.1	4.5	3.2	4.6	6.4	4.3	12.7	2.0	9.6	11.0
UL-A-RL	0.0	1.5	0.0	1.3	1.8*	2.1	0.0	2.0	1.2	0.0
Total	5.1	23.9	16.1	15.9	16.4	14.9	19.1	10.2	14.4	16.4
Tetramorphic										
W-UL-A-RL	0.0	2.9	1.1	2.0	1.8	0.0	0.0	0.0	0.0	1.8

*p<0.05, d.f. 4; **p<0.01, d.f. 4

TABLE 4 - Per cent frequencies of finger pattern combination types (PCT) and triradial pattern combination (PCT-tr.) frequencies among the Yanadi population.

Pattern combination	Male CY	Male IY	Male P1	Male HF	Male P2	Female CY	Female IY	Female P1	Female HF	Female P2
1. PATTERN COMBINATION TYPES (PCT)										
Monomorphic	12.82	7.46	5.38	12.57	12.87	2.13	9.53	8.16	12.06	10.31
Dimorphic	82.05	65.67	77.41	69.55	69.00	82.97	71.43	81.64	73.49	71.51
Trimorphic	5.13	23.89	16.13	15.89	16.37	14.90	19.04	10.20	14.45	16.36
Tetramorphic	0.0	2.98	1.08	1.99	1.76	0.0	0.0	0.0	0.0	1.82
2. PCT WITH TRIRADII (PCT-tr.)										
Monotriradial (PCT-1tr.)	12.82	2.98	10.75	6.62	5.26	8.51	11.11	12.24	12.06	6.67
Ditriradial (PCT-2tr.)	10.26	8.95	4.30	10.60	11.12	4.26	9.53	6.12	8.43	9.09
Tritriradial (PCT-3tr.)	76.92	67.17	70.96	70.86	73.68	78.71	73.01	75.52	75.90	76.36
Tetratriradial (PCT-4tr.)	0.0	20.90	13.99	11.92	9.94	8.52	6.35	6.12	3.61	7.88

TABLE 5 - Pattern combination indices based on 1. Pattern combination types (PCT) 2. triradial pattern combination (PCT-tr.)

Pattern combination index	Male					Female				
	CY	IY	P1	HF	P2	CY	IY	P1	HF	P2
1. PATTERN COMBINATION TYPES (PCT)										
M.I.	16.90	2.75	4.81	4.31	4.21	2.53	13.30	10.05	16.46	14.41
T.I	6.21	36.38	20.80	22.88	23.77	17.95	26.75	12.50	19.59	22.44
Q.I.	0.0	4.41	1.42	2.86	2.61	0.0	0.0	0.0	0.0	2.52
D.I	21.88	52.75	29.18	43.18	44.83	20.52	40.00	22.49	36.07	39.84
2. TRIRADIAL PATTERN COMBINATION TYPES (PCT-tr.)										
MT.I.	16.67	4.44	15.81	9.34	7.41	10.81	15.22	16.21	15.89	8.73
DT.I.	13.34	13.32	6.06	14.96	15.09	5.71	13.05	8.10	11.11	11.90
QT.I.	0.0	31.11	19.72	16.82	13.49	10.82	8.69	8.10	4.75	10.25
TT.I.	30.0	48.83	40.92	41.12	35.72	27.05	36.87	32.47	31.75	30.96

TABLE 6 - Per cent frequencies of 23 SDM (Shanon diversity measure) values of mono, di, tri and tetramorphic pattern combinations (FPC) among the Yanadi.

Rank	SDM	FPC No.	FPC Ratio	Yanadi male CY 39	IY 67	P1 93	HF 151	P2 171	Yanadi female CY 47	IY 63	P1 49	HF 83	P2 165
1	0.000	1	10:0	12.8	7.5	5.4	12.6	12.9	2.1	9.5	[illegible]	12.0	10.3
2	0.325	2	9:1	25.6	14.9	17.2	13.2	10.5	12.8	6.3	14.3	20.5	13.9
3	0.500	2	8:2	7.7	10.4	21.5	11.3	14.0	23.4	20.6	12.2	20.5	15.2
4	0.611	2	7:3	12.8	13.4	12.9	14.6	18.1	8.5	17.5	18.4	8.4	21.2
5	0.639	3	8:1:1	2.6	4.5	3.2	3.9	3.5	2.1	4.8	2.0	2.4	3.0
6	0.673	2	6:4	30.8	14.9	12.9	22.5	16.9	21.3	19.0	28.6	15.7	12.1
7	0.693	2	5:5	5.1	11.9	12.9	7.9	9.4	17.0	7.9	8.2	8.4	9.1
8	0.802	3	7:2:1	-	1.5	5.4	3.3	4.1	4.3	7.9	4.1	6.0	6 1
9	0.898	3	6:3:1	-	7.5	3.2	3.9	1.2	6.4	3.2	2.0	1.2	3.6
10	0.940	4	7:1:1:1	-	-	-	0.7	-	-	-	-	-	0.6
11	0.943	3	5:4:1	-	5.9	2.2	2.6	3.5	2.1	3.2	-	3.6	0.6
12	0.950	3	6:2:2	2.6	1.5	2.2	1.9	1.8	-	-	2.0	-	-
13	1.030	3	5:3:2	-	-	-	-	1.8	-	-	-	-	2.4
14	1.055	3	4:4:2	-	2.9	-	-	-	-	-	-	1.2	0.6
15	1.089	3	4:3:3	-	-	-	-	0.6	-	-	-	-	-
16	1.089	4	6:2:1:1	-	1.5	1.1	0.7	1.2					
17	1.168	4	5:3:1:1	-	-	-	0.7	0.6					
18	1.194	4	4:4:1:1	-	-	-	-	-					
19	1.221	4	5:2:2:1	-	-	-	-	-					
20	1.280	4	4:3:2:1	-	1.5	-	-	-					
21	1.314	4	3:3:3:1										
22	1.332	4	4:2:2:2										
23	1.366	4	3:3:2:2										

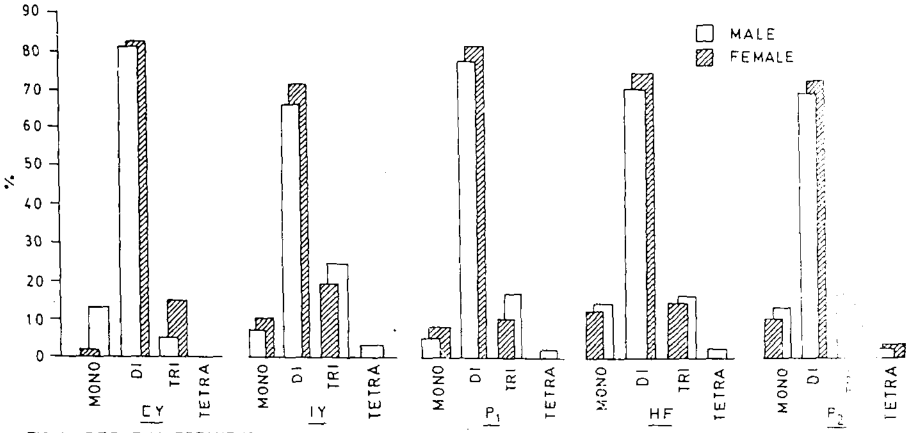

FIG. 1 PERCENT FREQUENCY OF PATTERN COMBINATION TYPES (PCT) AMONG THE YANADIS

Fig. 1 - Percent frequency of pattern combination types (PCT) among the Yanadi.

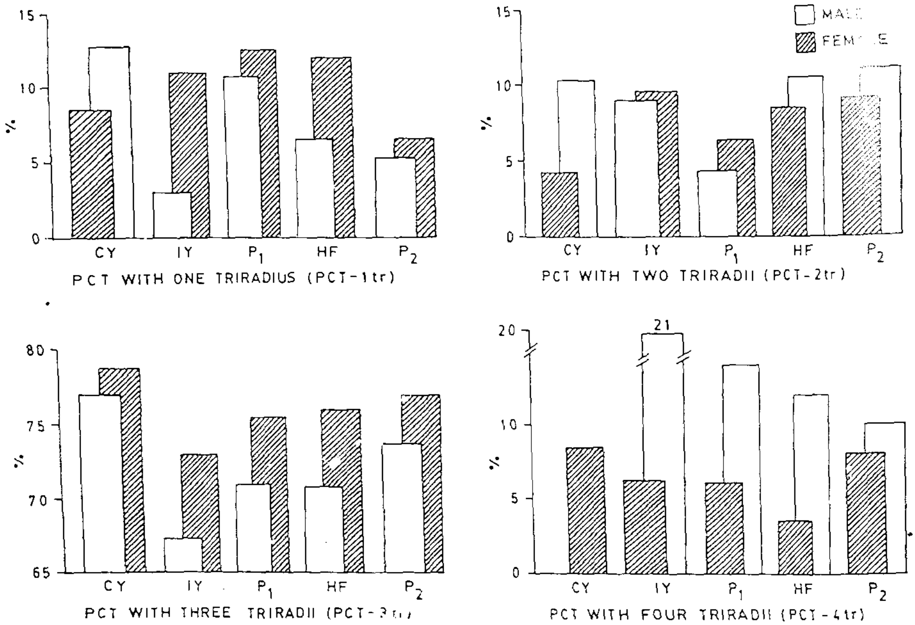

FIG. 2 PERCENT FREQUENCY DISTRIBUTION OF PATTERN COMBINATION TYPE (PCT) WITH NUMBER OF TRIRADII.

Fig.2 - Percent frequency distribution of pattern combination type with number of Triradii (PCT-tr.) among the Yanadi.

However all the PCR of the four categories, irrespective of different types (PCT), will be, i.e.,

$$\text{All the PCRs} = 1 + (n-1) + \sum_{n=3}^{10} (n-2) + \sum_{n=3}^{10} \sum_{k=3}^{10} (n-k)$$

Thus the pattern combinations can be considered in two different aspects 1). 15 pattern combination types (PCT) of 4 MONO, 6 DI, 4 TRI and 1 Tetramorphics and 2). a total of 130 different possible ratios that can possibly occur for each of the mono and polymorphic pattern combination on all the ten digits. viz., 1, 9, 36 and 84 ratios for the corresponding mono, di, tri and tetra morphic pattern combinations respectively.

But for all the 15 different pattern combination types (PCT) and all the pattern combination ratios (PCR) together, can be obtained by the binomial equation, viz.,

The total ratios are:

$$4_C1\ (1) + 4_C2\ (n-1) + 4_C3\ [\sum_{n=3}^{10} (n-2)] + 4_C4\ [\sum_{n=3}^{10} \sum_{k=3}^{10} (n-k)]$$

However, the total PCR (286) is too large to be handled for practical purposes, but this can be quantified by a suitable diversity measure (e.g. Shanon's entropy etc.). By using "Shanon's Diversity Measure" (PDI or SDM), 286 total PCR can be reduced to 23 different PDI (pattern diversity index) values (ranks) ranging from 0 to 1.3662. This has been attempted by Micle and Kobyliansky (1988). These 23 PDI or SDM correspond to all the ratios of mono and polymorphic pattern combinations. Table 2, shows 23 PDI values (rank) that correspond to PCR and PCT. For example, the four monomorphic pattern types do not show pattern diversity and therefore have a single PDI value zero.

The 54 ratios of 6 dimorphic types are reduced to 5 PDI values. Similarly 144 ratios of 4 trimorphic and 84 ratios of one tetramorphic combinations get reduced to 8 PDI and 9 PDI values respectively.

In the table, PDI rank values are grouped according to the pattern types, which inevitably introduces two inconsistencies in the rank order. Especially (a). rank 5 (PDI = 0.6390) and rank 10 (PDI = 0.9404) are not in order. (b). Further, the PDI values of pattern types for the pattern combination ratios 4:3:3 and 6:2:1:1: are same (1.0889), however they were given different PDI ranks viz., 15 and 16, so that they can be distinguished with reference to their corresponding pattern combination types (PCT) of trimorphic and tetramorphics respectively.

Populations can be compared for both the aspects of pattern combinations: viz., 1: if the pattern combination types (PCT) or triradial pattern combinations (PCT-tr.) are alone considered, this can be described as 'qualitative method' and 2. if pattern combination ratios (PCR) (irrespective of the PCT) are considered, which indicates the pattern diversity, it can be described as "quantitative method".

The difference between the qualitative (PCT or PCT-tr.) and the quantitative (PCR) methods is that all the four monomorphics has a PDI value zero, whereas the tetramorphics has 9 PDI values. The higher the PDI higher the pattern diversity.

Data and Analysis

Dermatoglyphic data were collected from all the available individuals from all the settlements of the five breeding populations, with an aim to cover the entire/most of the study unit.

However, in P1 region in one of the two settlements, (viz., 06 ALD) only three families could only be covered. The details of sample size are given in Table 1.

Analysis

The data on four basic pattern types were analyzed for both qualitative (PCT) and quantitative (PCR) methods. For PCT the frequencies of different pattern combinations are scored for 3 (out of four) monomorphic, 6 dimorphic, 4 trimorphic and one tetramorphic patterns and also for the four categories of PCT with 1, 2, 3, and 4 triradii. Pattern combinations involving penta morphic patterns were practically absent.

Indices

Further, four pattern combination indices based on PCT were newly defined. They are (i). Mono-Di Index - the percent proportion of monomorphic pattern types to dimorphic pattern types. (ii) 'Tri-di Index' and (iii) 'Tetra (quadra)-Di Index - are the proportions of tri and tetramorphic frequencies to dimorphic patterns, multiplied by 100. (iv) Dimorphic Index - the relative proportion of dimorphic patterns to the combined frequencies of mono, tri and tetramorphic frequencies.

Mono-di Index (M.I)= Freq. of monomorphics/Freq. of dimorphics x 100.

Tri-di Index (T.I) = Freq. of trimorphic/Freq. of dimorphics x100

Tetra-di Index (Q.I.) Freq. of tetramorphics/freq. of dimorphics x 100

Dimorphic Index (D.I.) = Freq. of dimorphic/ (Sum of the freq. of mono, tri and tetra morphics) X 100.

Based on triradial pattern combinations (PCT-tr.) the following five more indices were also defined. They are: (i) Mono-tri index, (ii) Di-Tri Index, (iii) Tetra (Quadra)-Tri Index and (iv) Zero-triradial index and (v) Tri-radial index are the percent frequencies of mono-tr. (PCT-1tr.), di-tr. (PCT-2tr.), tetra-tr. (PCT-4tr.) to PCT-3tr. frequency respectively, and the "tri-radial index" is the relative frequency of PCT-3tr. to the sum of PCT-0tr., PCT-1tr., PCT-2tr., and PCT-4tr. frequencies. These are:

Mono-tri Index (MT. I.) = Freq. of PCT-1tr./ Freq. of PCT-3tr. X100. Di-tri Index (DT.I.) = Freq. of PCT-2tr./Freq. of PCT-3tr. X 100. Tetra-tri Index (QT. I) = Freq. of PCT-4tr./Freq. of PCT-3tr. X100. Zero-tri Index (ZT. I) = Freq. of PCT-0tr./Freq. of PCT-3tr. X 100

Tri-triradial Index (TT.I.) = {Freq. of PCT-3tr /[PCT-0tr + PCT-1tr. + PCT-2tr. + PCT-4tr.]}x100

The four pattern combination indices of M.I., T.I., Q.I. and D.I. and the five triradial pattern combination indices of MT.I., DT.I., QT.I. ZT.I. and TT.I. frequencies are comared between the five Yanadi regional populations. The ZT.I. is practically absent in the case of ten digits but can be observed in bilateral or left/right (five digits) hands.

In the quantitative method the 23 PDI values are obtained by using Shanon's Entropy Measure for all the PCR for all the ten digits. This was adopted by Micles and Kobyliansky (1988).

$$PDI = - \sum_{i=1}^{K} p_i \log_e p_i$$

where p_i is the frequency ratios of ith pattern type combination for mono, di, tri, and tetramorphic combnations.

The percent frequencies of pattern combinations and PDI values for within and between population differences were tested for significance by T-statistics (Rao, 1973).

Results

Qualitative Analysis

Pattern combination types (PCT) and Triradial pattern combinations (PCT-Tr.)

A comparison of per cent frequencies of pattern combination types on fingers among the Yanadi populations (Table 3) show significant differences in trimorphic (W-UL-RL) and monomorphic types among males. In other combinations though the values are not significant, wide differences can be seen in case of monomorphic (W, UL), dimorphic (UL-RL) and trimorphic (UL-RL-A) frequencies. The female sample also maintains wide differences and it is noteworthy to observe the absence of tetramorphic pattern types except in P2 population of the tribe.

Of the four patterncombination types, the dimorphic PCT are most frequent, followed by trimorphic, monomorphic and tetramorphics (Table 4). There is a clear trend of significant sex differences in PCT frequencies; females consistently show higher frequencies than males in dimorphic patterns. An opposite trend is seen in case of trimorphic and tetramorphic types. Higher frequency of monomorphic patterns among females are observed in IY and P1 populations, whereas males predominate in CY, HF and P2 populations (Fig. 1).

When the PCT with triradii (PCT-tr) are considered PCT-3tr. are found to be most frequent among males and female samples. It is nearly seven times as frequent as PCT-2tr. Females tend to show a higher frequency both in PCT-1tr and in PCT-3tr., whereas males predominate in case of PCT-4tr. Of all the five populations, IY shows a significant sex difference in PCT-1tr. and PCT-4tr. frequencies (Table 4 and Fig. 2).

Pattern combination indices

The pattern combination indices based on PCT and PCT-tr. frequencies are compared for sex differences (Table 5). In general, both MT.I., QT.I. are higher than MI, QI, whereas, DT.I. (di-triradial pattern combination Index) are lower to trimorphic index. However, no such trend is seen among D.I. and TT.I. frequencies. Consistent sex difference, especially a higher frequency among males, is noticed in case of PCT-indices of D.I., Q.I. and also in TT.I. and QT.I. But in case of M.I., MT.I. in general, females tend to show higher values and there is clear absence of Q.I. values except in P2 population.

Quantitative analysis

Pattern combination ratios (PCR)

In quantitative method of pattern combinations (PCR), the 23 PDI ratios reveal wide differences among the Yanadis (Table 6). The results show heterogeneity in at least dimorphic and trimorphic PDI frequencies. Most of the tetramorphic (especially among females) and a few trimorphic ratios are absent. And a wide heterogeneity is observed in PDI rank 5 and 8 values that corresponds to dimorphic and trimorphic frequencies.

Males show differences in 8:2 (PDI rank 3); 6:4 (PDI rank 6); 7:2:1 and 6:3:1 (PDI rank 8 and 9) values and females show differences in 9:1, 7:3 and 6:4 (PDI ranks 2, 4 and 6), but the differences are not significant.

Discussion

The occurrence of four pattern frequencies of Whorl, Ulnar and Radial Loops, and Arches between the five breeding populations range from 42.7% to 49.9% for Whorls; 45 to 54.3% for Ulnar loops, 0.51 to 2.1% Radial loops and 1.4% to 2.5% for Arches respectively. These do not help in discriminating the five Yanadi populations and cannot be extended for further statistical analysis to investigate other aspects of population structure. But, on the otherhand, the results of pattern combination analysis clearly shows differences between populatoons and sexes, as against the classical method of comparison of percent frequencies of arch, loop and whorl patterns. In this respect, the validity of the method of pattern combinations for discrimination is more striking between nonnormal populations than perhaps among the subdivided populations. For example, Vasulu et al., (1991) have shown significant differences and unique pattern combinations (both PCT and PCR) in case of Downs syndrome, Schizophrenia and Sex-crime convicts.

The method of pattern combinations analysis include considering all ten digits together or an individual as the study unit, is a more reasonable criterion than the digital pattern frequency. To be specific, as pointed out by Howells (1969), an individual be it a bone or a tooth "is not a discrete assembly of independent measurements. Accordingly a specimen should be treated as a vector of measurements, as an integrated whole, not as an inventory of "separable figures". Considering all the digits together as one system is biologically more meaningful, especially, in view of the recent findings, that the digital patterns are correlated and that the ridge formation in all the fingers form continuous region (de Wilde, 1990). This indicates that the patterns are governed by a common biological process, possibly by a common set of genes. This is also supported by Robert and Coope's (1975) observation that the ten fingers are the phenotypic expressions of a common genotype which has a modyfing influence for each digital (pattern) configuration.

The manual (pedar) method of Poll or Takeya's bivariate digital distribution of pattern type frequencies, perhaps, contain all the information on pattern combination types, but the relative ratios of its occurrence of these patterns and the method of classification are not represented. It is possible to extract all the pattern combinations types from the bivariate distribution, but not the ratios/ proportions of occurrence and it was not considered by either Poll or Takeya in their proposed manual method. The study by Lu (1968) is more statistical oriented problem on discriminant function and similarly, Penrose and Loesch's topological method attempts the digital configuration pattern combination types into ulnar and radial components. These studies do not suggest a classification of qualitative and quantitative aspects of pattern combination types or its ratios for population affinities and for further analysis. Micle and Kobyliansky (1988) utilizes only the relative ratios of pattern combination but the qualitative aspects are not described. The proposed method takes into account of Lu (1968), Penrose and Loesch (1969, 1970) and Loesch (1975), and Micle and Kobyliansky (1988) and urther attempts a general classification of both the aspects of pattern combinations. The pattern intensity index also can be easily calculated from the pattern combination type sequences. Penrose and Loesch propose a digital coded pattern type sequences into ulnar and radial component, which was similar to Lu's attempt of digital coded pattern type sequences, except that it does not separately consider ulnar and radial components. This is similar to the PCT and PCT-tr. (pattern combinations and triradial pattern combination types) of the qualitative aspect of the proposed method, both describe the sequences of all the combination types and also the pattern intensity index. For example, both PCT and PCT-tr. types contain all digital coded dictionary of pattern configurations that were described by Lu (1968) and Loesch (1975) but (the difference is that in the present method) these are classified (qualitatively) according to the number of patterns involved and (quantitatively) according to the occurrence of pattern ratios/proportions with the underlying (theoretical expectations of) binomial combination, unlike the rank order sequence of all the data of Penrose and Loesch's method, which becomes difficult to tackle for large sample sizes except with the use of a computer. The difference is that the proposed method do not consider ulnar and radial components separately and it can be easily handled.

The results of the pattern combination analysis among the subdivided Yanadi tribal populations conform to the expectations as hypothesized based on population structure variables, which confirms the efficiency of pattern combination analysis in discriminating the subdivided populations. To be specific, IY which is an endogamous, spatially isolated with high levels of consanguinity also show unique pattern combinations of absence of monomorphic UL, dimorphic UL-RL and a high frequency of trimorphic W-UL-RL frequencies and least frequencies of PCT-1tr., and a high frequency of PCT-4tr. and correspondingly a low value of M.I., MT.I. and high frequncy of T.I., DT.I., Q.I. and QT.I. Further, an unique bilateral patterns of monomorphic A, ZT.I., and dimorphic W-RL also observed in case of IY population. In the same context, the contiguous populations of P1, HF and P2 show least differences in PCT, PCT-tr. and PCR as expected and is in agreement with other results obtained in anthropometry, quantitative dermatoglyphic characters (Vasulu and Pal, 1989; Vasulu, 1991; Vasulu, 1994).

One more aspect of the pattern combination analysis is that it has shown clear sex differences in some of the pattern combination frequencies, which can be seen in particular in PCT-tr frequencies (e.g., Fig. 2) and also in PCT and PCR, where they show absence of tetramorphic patterns, which was also confirmed by Micle and Kobyliansky (1987) among Israel Jews, where they show absence of tetramorphic PDI values. But the Bulgarian study do not show such clear sex differences in PDI values (Karov, 1990), perhaps it might show sex differences if the pattern combination types (both PCT and PCT-tr.) were also considered, since qualitative method has a better discriminatory capacity than quantitative method of pattern combination analysis, as was observed from the present study and from an early study (Vasulu et al., 1991). Possibly studies in different populations of the world might help in explaining the nature of sex difference in dermatoglyphics.

The pattern combination analysis holds potential for further investigation with respect to inbreeding, inheritance and in investigating asymmetry and some issues in population genetics of subdivided populations. Some of the results obtained in the study among the Yanadi, encourage the application of the method of pattern combination analysis in other biological parameters for investigating the anthropological genetic problems. Towards this direction the distribution pattern of pattern combination types of whorls, loops and arches in different populations, is another area of interest of this method both in view of statistical and genetic fields. A preliminary analysis indicate a leptokurtic, positively skewed distributi)r arches (and for radial loops), which was expected in view of its low frequency of urrence, whereas the loop and whorl appear to indicate nonnormal distribution and perha on independent but complementary to each other, the details of its relationship has been npted in a separate publication (Vasulu, 1996b). Another important dimension of the distrib on cuves of pattern combination types of whorl and loop is that it shows remarkable a striking differences between nonnormal and normal populations; for example, Downs synd ne cases shows logarithmic distribution in contrast to near normal distribution among t Yanadis (Vasulu, 1996b). It is possible that the pattern of distribution of whorls and loops ay quite vary in different populations, which might help in understanding the genetic pr iples of dermatoglyphic traits (pattern types) and triradial distribution and in general q ntitative characters with respect to multifactorial inheritance, similar to ridge count.

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