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# Principal components of finger ridge-counts: their universality

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**Summary.** A principal component analysis was carried out on radial and ulnar finger ridge-count data on a sample of fishermen of the sea coast of Puri in the state of Orissa in India. The component structure is very similar to that obtained earlier by Roberts and Coope for some English populations, by Arrieta and Lostao for a Basque population, by Siervogel *et al.* for a White American population, by Jantz and Hawkinson, and Jantz *et al.* for American and African populations, and by other authors for other populations. The initial components are bilaterally symmetric and the structure of these components is the same whether the two sides are taken separately or together. Only the latter components represent a certain amount of bilateral asymmetry. The first component is a 'size' component, indicating total finger ridge-count; the second component is a radial–ulnar contrast. From a comparison with previous studies on other populations, it appears that the component structure corresponding to the larger eigenvalues is fairly universal; there is a certain lack of universality in the structure of the components corresponding to smaller eigenvalues as well as in the order of these components, especially the rotated ones, when the corresponding eigenvalues are very close. As observed by previous authors, components corresponding to larger eigenvalues do not necessarily exhibit larger inter-population differences. However, there is lack of universality in the order of the components and in the structure of the components that exhibit large inter-population differences.

## 1. Introduction

The need for a multivariate approach to finger ridge-counts and the advantages it offers, compared to the summary measures such as TFRC/ATFRC, in tracing population relationships at local and racial levels has been amply demonstrated (Knussmann 1967, Chopra 1971, Jantz and Owsley 1977, Jantz and Hawkinson 1979, 1980, Jantz, Hawkinson, Brehme and Hitzeroth 1982). Many of the above studies show interpopulation consistency in the components derived, within major racial/geographical stocks, suggesting biological validity of the underlying component structure obtained by principal component analysis. Such a set of possible primary components of dermal patterns, which are universal in nature, has been explored by Lin, Crawford and Oronzi (1979). However, less obvious is the nature of variation in these components among the populations of different races. Therefore, Roberts and Coope (1975) stressed the need for elucidating this structure in samples of different races, geographical regions and/or continents, to ascertain if the component structure found in European populations is universal. Later, Jantz and Owsley (1977), Jantz and Hawkinson (1979, 1980) and Jantz *et al.* (1982), studying American White and Black and subsaharan and other African populations, found some evidence of racial variation, although a remarkable degree of overall consistency was seen in the component structure. Studies by Reed, Norton and Christian (1978) on an American population of twins, by Meier (1981) on Eskimo and East Polynesian populations, by Arrieta and Lostao (1988) on a Basque population, and by Santos, Meier and Vieira-Filho (1990) on an Amazonian Amerindian population demonstrated the universality of the component structure. Significant racial differences are also known to exist in the average inter-finger correlation of ridge-counts (Jantz 1977, Malhotra and Reddy 1986) which may reflect in the component structure as well. However, to date, no attempt has been made to study samples from Asia to discern their dermatoglyphic component structure. The present study essentially aims to fill this gap.

Principal component analysis is a general technique for reducing the dimensions of variability. This reduction technique looks for linear combinations of the original measurements which preserve as much of the variation as possible. The problem with 20 finger ridge-counts is to examine what linear combinations (variously called *factors* or *components*) of the counts explain the variations between individuals, and to determine whether these factors have natural interpretations and whether they have further genetic significance in terms of their ability to differentiate between genetically different groups. The computational technique of extracting principal components consists in the calculation of eigenvalues and eigenvectors of appropriate covariance or correlation matrices (Press 1972, Morrison 1976, Gower and Digby 1981).

## 2. Materials and methods

The populations studied are marine fishermen at Puri, a coastal town in the state of Orissa in India. There are three endogamous groups called *Vadabalija of Penticotta* (VP), *Vadabalija of Vadapeta* (VV) and *Jalary* (J). They are migrants and speak Telugu, a language spoken in the neighbouring state of Andhra Pradesh. While VP migrated some 35 years ago from about 48 villages distributed in East and West Godavari and Visakapatnam districts of Andhra Pradesh, the VV and J groups did so some 100 years ago from 42 and 17 villages respectively of the Srikakulam district of Andhra Pradesh and contiguous Ganjam district of Orissa. At Puri, the population sizes of the three groups are about 8000, 4000 and 800 respectively. More details of these populations, including their demographic structures and biological variations, can be found in Reddy (1984), Reddy, Chopra and Mukherjee (1987), Reddy, Chopra, Karmakar and Malhotra (1988) and Reddy, Chopra, Rodewaldt, Mukherjee and Malhotra (1989).

Finger ridge-count data on 676 individuals, both male and female, of these groups were utilized for the present study. Fingerprints were obtained during the years 1977–78 by ink-and-roller method (Cummins and Midlo 1961) and the ridge-counting was done by one of the authors (B.M.R.), following standard procedures (Holt 1968). Each individual is represented by a vector of 20 counts, a radial and an ulnar count for each digit. Sample sizes of males and females of these three groups are given in table 1.

## 3. Results

Table 1 presents the mean radial and ulnar ridge-counts in each digit for each of the six caste–sex groups as also the within-group standard deviation (SD). It is noticed that the means and SDs are of the same magnitude as in Jantz *et al.*'s (1982) data for some subsaharan African populations, for each of the digits. As is the case with other populations, the radial counts are much higher than ulnar counts and the digits 4 and 1 record higher counts. Previous authors have found evidence of variation in ridge-counts and components due to race and sex. Hence we computed the principal components for the six caste–sex groups separately; we found that there was very little variation in the component structure between the six groups. Hence we decided to compute a single set of principal components for the six groups after eliminating the caste–sex mean effects. To this end, we carried out a multivariate analysis of variance of all the 20 counts by caste and sex, to obtain an estimate of an assumed common covariance matrix of the six groups as the within-group covariance matrix. We

Table 1. Mean radial (R) and ulnar (U) ridge counts for each of the six caste–sex groups in each digit and within-group standard deviation.

| Caste-sex group | Sample size | Side | Digit 5 R | 5 U | Digit 4 R | 4 U | Digit 3 R | 3 U | Digit 2 R | 2 U | Digit 1 R | 1 U |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VP | | Left | 14·106 | 2·161 | 16·391 | 6·894 | 13·870 | 3·702 | 9·491 | 6·497 | 16·199 | 7·907 |
| Male | 161 | Right | 13·851 | 2·714 | 16·199 | 7·820 | 13·012 | 3·516 | 9·559 | 6·677 | 18·180 | 7·733 |
| VP | | Left | 13·680 | 1·930 | 15·500 | 6·660 | 12·660 | 3·830 | 9·830 | 6·030 | 15·080 | 6·460 |
| Female | 100 | Right | 13·490 | 1·660 | 16·350 | 7·230 | 12·760 | 2·130 | 10·670 | 5·160 | 16·770 | 5·340 |
| VV | | Left | 14·676 | 3·108 | 17·333 | 8·863 | 14·510 | 5·176 | 11·804 | 7·804 | 16·441 | 8·745 |
| Male | 102 | Right | 14·127 | 3·382 | 16·971 | 9·471 | 13·392 | 4·216 | 11·500 | 9·147 | 17·814 | 10·098 |
| VV | | Left | 13·977 | 2·565 | 16·901 | 8·618 | 13·000 | 6·107 | 10·496 | 7·931 | 14·168 | 7·771 |
| Female | 131 | Right | 13·901 | 1·947 | 16·588 | 8·267 | 12·977 | 4·992 | 11·244 | 8·206 | 16·130 | 6·863 |
| J | | Left | 14·206 | 1·931 | 17·366 | 8·427 | 13·947 | 5·641 | 10·359 | 5·962 | 16·275 | 6·229 |
| Male | 131 | Right | 13·748 | 2·725 | 16·176 | 9·855 | 12·092 | 5·237 | 9·824 | 7·511 | 18·191 | 8·473 |
| J | | Left | 12·275 | 1·196 | 15·902 | 7·902 | 14·118 | 5·157 | 9·941 | 6·627 | 14·647 | 8·471 |
| Female | 51 | Right | 11·902 | 2·059 | 15·020 | 9·176 | 13·020 | 4·353 | 10·745 | 7·549 | 15·392 | 7·039 |
| All | | Left | 13·985 | 2·231 | 16·652 | 7·864 | 13·652 | 4·895 | 10·287 | 6·809 | 15·574 | 7·359 |
| Groups | 676 | Right | 13·682 | 2·463 | 16·320 | 8·565 | 12·848 | 4·099 | 10·484 | 7·416 | 17·311 | 7·658 |
| Within- | | Left | 4·59 | 4·40 | 5·49 | 7·26 | 5·59 | 7·43 | 6·30 | 7·48 | 6·10 | 8·11 |
| groups SD | | Right | 4·70 | 4·56 | 5·65 | 7·28 | 5·05 | 7·08 | 6·05 | 7·71 | 6·21 | 8·07 |
| Caste | | Left | 1·31 | 0·17 | 0·40 | 0·22 | 1·09 | 0·43 | 1·02 | 0·27 | 0·53 | 0·51 |
| $F(2,670)$ | | Right | 1·54 | 0·32 | 0·62 | 0·12 | 0·89 | 1·47 | 0·84 | 0·26 | 0·60 | 0·56 |
| Sex | | Left | 7·28 | 1·93 | 4·24 | 0·31 | 3·41 | 0·10 | 0·79 | 0·31 | 11·11 | 1·18 |
| $F(1,670)$ | | Right | 4·40 | 7·87 | 0·99 | 1·89 | 0·04 | 0·73 | 1·42 | 1·07 | 14·71 | 12·58 |

extracted the correlation matrix from the within-group covariance matrix for a component analysis. In general, the principal components obtained from the covariance matrix and the correlation matrix are not the same, since principal components are not invariant under linear transformations. We chose to use the correlation matrix rather than the covariance matrix since the former is somewhat more standard and most of previous authors have used the correlation matrix; Roberts and Coope (1975), however, have used the covariance matrix.

The within-group correlation matrix has certain interesting features. The highest level of correlation is between homologous counts; for instance, radial left 5 count is most correlated with radial right 5; this kind of correlation is of the order of 0·6–0·7. The next level of correlation is between neighbours on the same side; for instance, radial left 5 is fairly highly correlated with radial left 4 and the correlations decrease gradually from digit 5 to digit 1; the range is from about 0·6 to 0·3. The third level of correlations is between a count and its neigbours on opposite sides; this varies between 0·35 and 0·25. The least correlations are between radial and ulnar counts and the above pattern is followed in the same order. That is, the least correlation is between a radial count and an ulnar count on different sides between digits far apart. This is as low as 0·2. The following correlations between radial left 3 (RL3) and other counts is a typical example of this description:

*Correlations between RL3 and other counts*

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| RL5 | UL5 | RL4 | UL4 | UL3 | RL2 | UL2 | RL1 | UL1 | |
| 0·38 | 0·44 | 0·59 | 0·47 | 0·45 | 0·63 | 0·42 | 0·42 | 0·31 | |
| RR5 | UR5 | RR4 | UR4 | RR3 | UR3 | RR2 | UR2 | RR1 | UR1 |
| 0·40 | 0·43 | 0·56 | 0·46 | 0·72 | 0·44 | 0·60 | 0·41 | 0·42 | 0·27 |

The pattern of the correlation matrix described here is similar to that presented by previous authors (Holt 1951, Siervogel, Roche and Roche 1978). Holt (1951) and Singh, Aitkin and Westwood (1977) have described the correlation structure in terms of three levels similar to the first three levels described here. We carried out principal component analysis on this correlation matrix. Often, in principal component analysis and in factor analysis, components or factors are 'rotated'; that is, a linear transformation on the initially obtained components is carried out, in order to make them more easily interpretable by having, for instance, a large number of zero coefficients. We also rotated the components so that we could compare the rotated components with such components obtained by other authors.

The results of component analysis are given in tables 2 and 3. Besides the first six components, we have presented components 12 and 16, in view of the fact that there are significant differences in these components between castes. Although we have also computed the rotated components, we have not presented the details, and have included here only a discussion of their comparison with rotated components of previous authors. The components—the unrotated as well as the rotated ones—are strikingly similar to those presented by Roberts and Coope (1975), Jantz and Owsley (1977), Siervogel *et al.* (1978), Reed *et al.* (1978), Jantz and Hawkinson (1979, 1980), Meier (1981), Jantz *et al.* (1982), Arrieta and Lostao (1988) and Santos *et al.* (1990). There are, of course, a few differences. We first describe the unrotated components and compare them mainly with those of Jantz *et al.* (1982) for subsaharan African populations and of Arrieta and Lostao (1988) for a Basque population. The first component explained 49% of the variance, the next 8·5%, then 6·4%, etc. The first

Table 2. Eigenvalues ($\lambda_k$) of within-group correlation matrix, proportion of variance explained, $\chi^2$ for equality of last eigenvalues and test for significance of last eigenvalues.

| $k$ | $\lambda_k$ | $\frac{\lambda_k}{20}$ | $\chi^2$ | d.f. | $\frac{\sqrt{n}\sum_{i=k+1}^{20}\lambda_i}{\sqrt{2\sum_{i=k+1}^{20}\lambda_i^2}}$ |
|---|---|---|---|---|---|
| 1 | 9·80 | 0·490 | 3100 | 189 | 113·19 |
| 2 | 1·70 | 0·085 | 2200 | 170 | 65·77 |
| 3 | 1·28 | 0·064 | 1597 | 152 | 65·41 |
| 4 | 1·18 | 0·059 | 1223 | 135 | 64·63 |
| 5 | 0·90 | 0·045 | 686 | 119 | 64·14 |
| 6 | 0·66 | 0·033 | 560 | 104 | 64·12 |
| 7 | 0·55 | 0·027 | 368 | 90 | 62·88 |
| 8 | 0·52 | 0·026 | 298 | 77 | 61·25 |
| 9 | 0·43 | 0·022 | 226 | 65 | 59·08 |
| 10 | 0·41 | 0·021 | 153 | 54 | 56·85 |
| 11 | 0·33 | 0·017 | 127 | 44 | 54·04 |
| 12 | 0·32 | 0·016 | 100 | 35 | 51·08 |
| 13 | 0·30 | 0·015 | 82 | 27 | 47·88 |
| 14 | 0·29 | 0·014 | 59 | 20 | 44·53 |
| 15 | 0·26 | 0·013 | 47 | 14 | 40·71 |
| 16 | 0·24 | 0·012 | 39 | 9 | 36·46 |
| 17 | 0·23 | 0·012 | 34 | 5 | 31·60 |
| 18 | 0·22 | 0·010 | 32 | 2 | 25·87 |
| 19 | 0·19 | 0·010 | — | — | 18·32 |
| 20 | 0·18 | 0·009 | — | — | — |

component has its weights fairly evenly distributed over all the 20 counts, the weights ranging from 0·50 to 0·78, the radial counts getting somewhat larger weights. The homologous digits get similar weights. This could be called the 'size' component. The second component, which explains 8·5% of the variance, seems to be a contrast between radial and ulnar counts, the radial counts getting a positive sign and ulnar negative sign; in this component, too, the homologous digits have similar weights; however, there is a great deal of variation in the inter-digit weights; the ulnar 1 and radial 5 carry very little weight, the dominating digits being 4 and 3. This is slightly different from Jantz *et al.*'s second component in that it excludes digit 2 but includes digit 1. The third component, which explains 6·4% of the variance, is a contrast between digit 1 and the others, notably digit 4; here again there is no left–right difference; the ulnar counts play a minor role in this component except for digit 1. This is exactly like Jantz *et al.*'s fourth component, but it is the same as Arrieta and Lostao's third component. Our fourth component is a contrast between ulnar 5 and ulnars 3 and 2; other digit counts have very little weights; left and right weights once again are similar. This is somewhat like Jantz *et al.*'s third component and Arrieta and Lostao's male fourth component. Thus our third and fourth components correspond to Jantz *et al.*'s fourth and third components respectively, but are similar to corresponding components of Arrieta and Lostao. This may well be due to sampling fluctuations in view of these two eigenvalues being very close: 1·28 and 1·18 in our case, 1·49 and 1·24 in Jantz *et al.*'s case and 1·27 and 1·23 in Arrieta and Lostao's case. The fifth component is the difference between radial 5 and radials 3 and 2, but is not very clear-cut; the left and right weights are, however, similar; this component is different from Jantz *et al.*'s. The sixth component has significant weights only for digits 2 and 1,

Table 3. Loadings of the first six and the twelfth and sixteenth principal components.

| Digit | Radial (R)/ulnar (U) | Component 1 | 2 | 3 | 4 | 5 | 6 | 12 | 16 |
|---|---|---|---|---|---|---|---|---|---|
| L5 | R | 0·78 | 0·11 | −0·15 | 0·07 | −0·40 | 0·06 | 0·04 | −0·18 |
| | U | 0·50 | −0·47 | 0·03 | 0·59 | −0·04 | 0·05 | 0·15 | 0·11 |
| L4 | R | 0·78 | 0·22 | −0·28 | 0·16 | −0·19 | 0·05 | 0·11 | −0·05 |
| | U | 0·78 | −0·23 | 0·09 | 0·07 | 0·09 | −0·03 | 0·10 | −0·24 |
| L3 | R | 0·78 | 0·28 | −0·17 | −0·01 | 0·17 | −0·08 | −0·31 | −0·01 |
| | U | 0·70 | −0·39 | −0·00 | −0·26 | 0·21 | 0·05 | 0·00 | −0·04 |
| L2 | R | 0·72 | 0·18 | −0·07 | 0·09 | 0·20 | −0·35 | 0·10 | 0·03 |
| | U | 0·73 | −0·22 | 0·11 | −0·30 | 0·05 | 0·14 | −0·14 | 0·15 |
| L1 | R | 0·64 | 0·39 | 0·39 | 0·20 | 0·13 | 0·27 | 0·03 | 0·07 |
| | U | 0·59 | −0·09 | 0·59 | −0·08 | −0·20 | −0·29 | −0·01 | −0·05 |
| R5 | R | 0·77 | 0·14 | −0·16 | 0·00 | −0·41 | 0·01 | −0·16 | 0·04 |
| | U | 0·54 | −0·47 | −0·04 | 0·54 | −0·08 | 0·07 | −0·16 | −0·07 |
| R4 | R | 0·76 | 0·23 | −0·27 | −0·14 | −0·23 | 0·02 | 0·22 | 0·10 |
| | U | 0·76 | −0·18 | −0·23 | 0·02 | −0·04 | 0·00 | 0·04 | 0·26 |
| R3 | R | 0·79 | 0·28 | 0·13 | 0·09 | 0·19 | 0·00 | −0·11 | −0·01 |
| | U | 0·70 | −0·38 | −0·03 | −0·30 | 0·25 | 0·08 | −0·06 | 0·01 |
| R2 | R | 0·67 | 0·21 | −0·10 | 0·18 | 0·35 | −0·34 | 0·08 | −0·01 |
| | U | 0·70 | −0·27 | 0·05 | −0·32 | 0·05 | 0·18 | 0·15 | −0·11 |
| R1 | R | 0·61 | 0·44 | 0·37 | 0·17 | 0·15 | 0·36 | 0·06 | −0·04 |
| | U | 0·61 | −0·04 | 0·56 | −0·13 | −0·23 | −0·23 | −0·01 | 0·05 |

positive weights for radial 1 and ulnar 2 and negative weights for ulnar 1 and radial 2—this could be described as interaction between radial vs. ulnar and digit 2 vs. digit 1.

We made an attempt to interpret the remaining components but they are not clearly interpretable. Other authors (for instance Siervogel *et al.* 1978) have noted that components after the tenth display bilateral asymmetry, although as noted earlier this asymmetry is not represented in the initial components. We notice that the latter components do contain a certain amount of bilateral asymmetry in the sense of homologous digits having opposite signs; however, the weights are not similar in magnitude. Further, none of these components reflects exclusively bilateral asymmetry; this asymmetry is mixed up with digital differences; more importantly, some components appear to be interactions between digital differences and bilateral asymmetry. For instance the twentieth component is: (digit 5 vs. digit 4) × (left vs. right). In view of lack of clarity of the latter components we have not presented them all.

The structure of the components described above establish this universality of a clear tripartite division of digits observed by Siervogel *et al.* (1978), Reed *et al.* (1978), Meier (1981) and Santos *et al.* (1990). Thus there seem to be distinct digital regions, digit 1, digits 2 and 3, and digits 4 and 5, digit 4 being unstable, sometimes with digits 2 and 3 and sometimes with digit 5, depending upon the population and the component. Lin, Crawford and Oronzi (1979) explored possible universally valid dermal patterns, using the technique of principal component analysis; they present six components based on 24 variables. In their analysis they use only the left side observations; besides the 10 ulnar and radial ridge-counts they use the 10 radial and ulnar side numbers of triradii and three interdigital ridge-counts (*a-b*, *b-c*, *c-d*) and *atd* angle. In view of these differences from our analysis, it is rather difficult to compare our results with theirs.

Except for a few of the latter components, no component included left-right difference and hence perhaps the analysis could as well be carried out pooling left and right ridge-counts. Tables 4 and 5 give the eigenvalues and the components in terms of

Table 4. Eigenvalues ($\lambda^k$) of within-group correlation matrix and proportion of variance explained on the basis of left–right pooling.

| $k$ | $\lambda_k$ | $\frac{\lambda_k}{10}$ | $k$ | $\lambda_k$ | $\frac{\lambda_k}{10}$ |
|---|---|---|---|---|---|
| 1 | 5·71 | 0·571 | 6 | 0·39 | 0·039 |
| 2 | 0·99 | 0·099 | 7 | 0·31 | 0·031 |
| 3 | 0·74 | 0·074 | 8 | 0·25 | 0·025 |
| 4 | 0·69 | 0·069 | 9 | 0·23 | 0·023 |
| 5 | 0·51 | 0·051 | 10 | 0·18 | 0·018 |

Table 5. Loadings of the first six principal components on the basis of left–right pooling.

| | | Component | | | | | |
|---|---|---|---|---|---|---|---|
| Digit | Radial (R)/ulnar (U) | 1 | 2 | 3 | 4 | 5 | 6 |
| 5 | R | 0·57 | 0·51 | −0·12 | −0·61 | 0·05 | −0·07 |
| | U | 0·81 | −0·14 | −0·15 | −0·02 | 0·43 | −0·18 |
| 4 | R | 0·83 | 0·22 | −0·18 | −0·01 | −0·01 | 0·13 |
| | U | 0·81 | −0·24 | −0·24 | 0·20 | 0·26 | −0·03 |
| 3 | R | 0·75 | 0·41 | 0·02 | 0·30 | −0·24 | −0·07 |
| | U | 0·84 | −0·31 | −0·17 | −0·01 | −0·17 | 0·02 |
| 2 | R | 0·79 | 0·27 | 0·14 | 0·33 | −0·06 | −0·16 |
| | U | 0·78 | 0·24 | 0·13 | −0·13 | 0·32 | 0·36 |
| 1 | R | 0·66 | 0·08 | 0·65 | −0·15 | 0·20 | 0·29 |
| | U | 0·66 | −0·45 | 0·36 | −0·25 | −0·15 | −0·36 |

these 10 pooled counts. It is clear that more or less the same components are obtained with the pooling of left and right counts.

Table 2 contains also the results of testing the significance of the components and of testing the equality of the eigenvalues after a certain stage. The $\chi^2$ statistic tests whether the eigenvalues from $k$ onwards are equal, that is, $\lambda_k = \lambda_{k+1} = \ldots = \lambda_{20}$. The statistic

$$\frac{\sqrt{n} \sum_{i=k+1}^{20} \lambda_i}{\sqrt{2 \sum_{i=k+1}^{20} \lambda_i^2}}$$

with a standard normal distribution tests whether the eigenvalues after the $k$th are significantly different from zero, that is, $\lambda_{k+1} = \lambda_{k+2} = \ldots = \lambda_{20} = 0$. Our results show that both hypotheses are rejected even at 1% for any value of $k$. This means that from no stage could we consider the eigenvalues to be equal or equal to zero.

Jantz *et al.* (1982) have pointed out that the first components need not necessarily be the most important with respect to explaining inter-population differences. Considering the original counts on each digit, we found that none of the 20 counts presented significant differences between castes (the largest $F(2670)$ is 1·54 with a $p$-value of 0·216). However, UL5, UL4, UL1, RR5, UR5, RR1, UR1 all presented significant sex differences at the 5% level. We carried out individual analysis of variance by caste and sex of each of the 20 components. Results are presented in table 6. No component has a

Table 6. Mean values of the 20 components for each of the six caste–sex groups and $F$-ratios for caste and sex differences thereof.

| | Caste–sex group | | | | | | | $F$-Ratios | |
|---|---|---|---|---|---|---|---|---|---|
| | VP | | VV | | J | | All | Caste | Sex |
| Component | M | F | M | F | M | F | Groups | $F(2,670)$ | $F(1,670)$ |
| 1 | 29·31 | 29·32 | 31·34 | 30·01 | 28·78 | 29·27 | 29·61 | 2·54 | 1·58 |
| 2 | 1·55 | 1·19 | 0·46 | 0·05 | 1·68 | 0·58 | 0·99 | 3·47 | 2·50 |
| 3 | 6·45 | 6·50 | 5·25 | 4·87 | 6·50 | 4·72 | 5·85 | 5·40 | 3·28 |
| 4 | 12·57 | 10·15 | 12·93 | 10·86 | 13·47 | 10·41 | 11·95 | 0·58 | 23·35 |
| 5 | 15·94 | 15·60 | 16·21 | 15·66 | 16·56 | 14·88 | 15·91 | 0·08 | 3·31 |
| 6 | 14·69 | 13·43 | 13·55 | 12·64 | 14·97 | 11·90 | 13·78 | 2·32 | 18·57 |
| 7 | 9·86 | 9·24 | 9·83 | 8·49 | 9·66 | 7·87 | 9·31 | 0·86 | 6·81 |
| 8 | 12·22 | 11·45 | 12·44 | 11·70 | 12·74 | 10·96 | 12·04 | 0·15 | 7·20 |
| 9 | 10·26 | 9·75 | 9·93 | 10·34 | 10·14 | 9·66 | 10·08 | 0·11 | 0·25 |
| 10 | 19·80 | 17·91 | 18·63 | 16·85 | 18·91 | 16·68 | 18·36 | 2·41 | 15·40 |
| 11 | 26·06 | 25·15 | 27·40 | 25·15 | 26·82 | 24·42 | 25·97 | 0·45 | 7·07 |
| 12 | 0·75 | 0·32 | −0·29 | −1·34 | 0·64 | −0·84 | −0·15 | 4·08 | 5·44 |
| 13 | 8·14 | 6·76 | 7·49 | 6·64 | 7·51 | 6·26 | 7·28 | 0·57 | 6·71 |
| 14 | 8·76 | 7·09 | 8·27 | 6·80 | 9·41 | 6·74 | 8·03 | 0·73 | 25·84 |
| 15 | 19·06 | 18·00 | 19·50 | 17·75 | 19·08 | 17·10 | 18·57 | 0·32 | 8·88 |
| 16 | 11·80 | 10·96 | 9·62 | 8·93 | 10·57 | 7·56 | 10·23 | 11·40 | 10·82 |
| 17 | 17·61 | 16·44 | 18·56 | 16·13 | 17·75 | 16·08 | 17·21 | 0·19 | 8·53 |
| 18 | 8·06 | 6·85 | 8·15 | 7·28 | 8·12 | 5·46 | 7·56 | 1·97 | 18·64 |
| 19 | 12·84 | 11·90 | 12·85 | 11·15 | 11·77 | 11·69 | 12·08 | 0·75 | 4·44 |
| 20 | 23·91 | 21·90 | 23·96 | 21·90 | 24·18 | 21·09 | 23·07 | 0·07 | 13·31 |
| | | | | | | | | 2·22 | 3·05 |
| Sample size | 161 | 100 | 102 | 131 | 131 | 51 | 676 | ($F(40,1304)$) $p=0·000$ | ($F(20,651)$) $p=0·000$ |

$F(2,670)$ upper 5% point = 3·00; upper 1% point = 4·61.
$F(1,670)$ upper 5% point = 3·84; upper 1% point = 6·63.

significant caste × sex interaction. Only for components 2, 3, 12 and 16 is there a significant (at the 5% level) caste difference, the sixteenth being the highest. The twelfth and sixteenth components, however, appear peculiar and are not easily interpreted; the twelfth is UL5 − RL3 − RR5 − UR5 + RR4 + UR2 and the sixteenth is − RL5 + UL5 − UL4 + UL2 + RR4 + UR4 − UR2. All components except the first, second, third, fifth and ninth showed sex differences, the fourteenth being the most significant.

In table 7 of Jantz *et al.* (1982), quite a few of the latter components showed significant population differences while the initial ones did not. In table 2 of Jantz and Hawkinson (1980), components 6 and 15 showed significant population differences. If the object of getting linear components is to exhibit large population differences, then the canonical variables of discriminant analysis are the best candidates; for they maximize inter-group differences. There is no reason why the initial principal components should display large population differences; they only display large within-group differences. An approximate picture that emerges out of an examination of Jantz *et al.*'s (1982) tables 6 and 7, Jantz and Hawkinson's (1980) tables 2 and 3 and the last columns of our table 6, is as follows: what components, whether initial or latter ones, display larger population differences will depend upon the distances between the populations under consideration. The major groups of subsaharan African populations showed more differences in the initial components; the mixed-up groups of American Black and White and Black African Yoruba populations showed differences in the earlier (sixth) as well as in later (fifteenth) components; in the relatively more homogeneous Black African groups the significant components were down the table, and in our case of caste groups belonging to the same village, the significant components went further down the table. Our populations showed significant overall differences on the basis of all the 20 ridge-counts, but our sample size and the degrees of freedom were large. The Mahalanobis distances between our caste groups were: between 1 and 2: 0·41; between 2 and 3: 0·63; between 1 and 3: 0·65; these are considerably lower than those between the groups in Jantz *et al.*'s displayed in their table 6, as well as in Jantz and Hawkinson's table 3. We carried out a caste discriminant analysis and the canonical variables in that discriminant analysis turned out, as expected, to be a combination of our components 12 and 16. This supports Jantz *et al.*'s (1982) contention that the first components need not necessarily be genetically the most important.

We rotated the components using Varimax rotation. The rotated components are quite similar to the rotated components of Jantz and Owsley (1977), Siervogel *et al.* (1978), Meier (1981), Arrieta and Lostao (1988) and Santos *et al.* (1990). The first factor is a general radial factor with large and somewhat equal weights for radial counts and small weights for ulnar counts. The second factor is dominated by radial 1 and 3. The third factor is ulnar 1, 2 and 3. The fourth factor is radial 2 and 3. The fifth is radial 4 and 5. The sixth is ulnar 5 left. The seventh is ulnar 1 and the eighth is ulnar 5 right. There were hardly any purely bilateral asymmetry components; this was also the case with Siervogel *et al.* (1978). Jantz and Owsley (1977) discern three general types of factors—radial count factors, ulnar count factors and thumb factors, specifically, radial 1, 2, 3; radial 4, 5; ulnar 1, 2, 3; ulnar 5; and ulnar 1. Our components match fairly well with this structure. Arrieta and Lostao (1988) discern a radial vs. ulnar component, which is not present in either ours or in Jantz and Owsley's. Arrieta and Lostao discern components for digit 1, for digits 2, 3, 4 and for digit 5, with instability for digit 4 which sometimes appears with digits 2 and 3 and sometimes with digit 5. Our component structure is also similar to this. Our component structure is also fairly similar to that of Siervogel *et al.* (1978); however, the order of the components is slightly different. There is an interchange of rotated components 1 and 2 between ours and Siervogel *et al.*'s (1978); in their digits 1, 2 and 3 dominate the first component and digits 4 and 5 the second. Component 3 is similar in both cases. Component 4 is a combination of our 5 and 6. Component 5 is like our 7. These differences could be attributed to the small differences in the corresponding eigenvectors, subjecting the order of the components to sampling fluctuations.

Most of the computations presented here were done using SPSS facility at the Indian Statistical Institute.

## 4. Discussion

There is a remarkable degree of universality in the correlation and the component structures in terms of the percentage variance explained by components, the components themselves and their variations over populations and sex. There are some minor differences, which may be attributable to the relative homogeneity of the three caste groups when compared to those of the populations considered by previous authors. The ethnohistorical information on our groups suggests that they are offshoots of a common stock in the relatively recent past and are observed to be at the initial stages of genetic differentiation (Reddy *et al.* 1989). In fact, two of these three groups are reproductive isolates of the same caste (Reddy 1984).

The three-level pattern of the correlation matrix observed in previous studies is reflected in our data and hence it is not surprising that the component patterns are also similar to those of the previous studies. The three-zone pattern of digit 1, digits 2 and 3, digits 4 and 5 noted by Siervogel *et al.* (1978) is observed here in a slightly different form. Our results in general confirm the field theory proposed by Roberts and Coope (1975). The absence of bilateral asymmetry in the initial components is also a universal phenomenon and is somewhat stronger in our case compared to those of the previous studies; we wonder whether this could also be due to the lower hierarchical level of the populations that we have worked with; there was not enough information on the latter components in the previous published work for us to make a conjecture on this issue. Another aspect of the consistency is that the most important components in terms of the variance explained are not necessarily the most important in terms of their ability to explain population and sex differences. As in previous studies, the components that discriminate best are some of the components corresponding to small eigenvalues—the sixth, twelfth and sixteenth, for instance.

On the basis of the overall consistency and similarity in the component structure observed not only between subgroups within racial/geographical groups, but also between racial/major geographical groups, it is tempting to conclude that these components are universal and may have biological validity as well; it must nevertheless be remembered that neither the present samples nor those of the previous studies are adequate representations of the racial/major geographical stocks that they stand for. However, taking into account the overall consistency, the nature of the differences and the types of populations used in various studies, it may at least be surmised that although the component structure has a large degree of universality, different components are useful in differentiating populations at different levels; to get a clear picture of this phenomenon it seems necessary to carry out a unified study of the role of the components in differentiating populations at various levels of hierarchy of the human species. Such a study would need more extensive data. We are currently attempting to carry one out using published and other available data on populations from across the world.

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**Zusammenfassung.** Radiale und ulnare Hautleistendaten einer Stichprobe von Fischern aus der Küstenregion von Puri im indischen Bundesstaat Orissa wurden mittels der Principal Component Analyse ausgewertet. Die Komponentenstruktur ähnelt stark der von Roberts und Coope für einige englische Populationen, von Arrieta und Lostao für eine baskische Population, von Siervogel *et al.* für eine Population amerikanischer Weißer, von Jantz und Hawkinson sowie Jantz *et al.* für amerikanische und afrikanische Populationen sowie von anderen Autoren für weitere Populationen beschriebenen. Die ersten Komponenten sind bilateral symmetrisch und die Struktur dieser Komponenten ist unabhängig davon, ob die beiden Seiten getrennt oder gemeinsam betrachtet werden. Ledliglich die nachfolgenden Komponenten repräsentieren ein gewisses Maß bilateraler Asymmetrie. Die erste Komponente ist eine "Größen"-Komponente, die die Gesamtleistenzahl anzeigt, die zweite Komponente spiegelt einen radial-ulnaren Kontrast wider. Ein Vergleich mit den Ergebnissen anderer Studien eigt, daß die Komponentenstruktur, die den größeren Eigenwerten entspricht, ziemlich universal ist. Es gibt einen gewissen Mangel an Universalität in der Struktur der Komponenten, die kleineren Eigenwerten entsprechen, wie auch in der Reihenfolge dieser Komponenten, speziell der rotierten, wenn die entsprechenden Eigenwerte eng beieinander liegen. Wie von anderen Autoren bereits gezeigt, reflektieren Komponenten, die größeren Eigenwerten entsprechen, nicht notwendigerweise größere Differenzen zwischen den Populationen. Es gibt jedoch einen Mangel an Universalität in der Reihenfolge der Komponenten und in der Struktur derjenigen Komponenten, die grwße Differenzen zwischen den Populationen widerspiegeln.

**Résumé.** Une analyse en composantes principales a été effectuée sur des données du nombre de crètes ulnaires et radiales d'un échantillon de pêcheurs de la côte de Puri dans l'état d'Orissa en Inde. La structure des composantes est très proche de celles obtenues antérieurement par Roberts et Coope pour quelques populations anglaises, par Arrieta et Lostao dans une population basque, par Siervogel *et al.* pour une population blanche américaine, par Jantz et Hawkinson et Jantz *et al.* pour des populations américaines et africaines et par d'autres auteurs pour d'autres populations. Les composantes intiales sont bilatéralement symétriques et leur structure est la même, que les deux côtés soient pris séparément ou ensemble. Seuls les composantes suivantes présentent une certaine quantité d'asymétrie bilatérale. La première composante est une composante de "taille", indiquant le nombre de crête digitales total, la seconde traduit le contraste entre ulnaire et radial. En comparant ces résultats avec ceux d'autres études, il apparait que la structure des composantes correspondant aux valeurs propres les plus grandes est universelle; c'est moins vrai pour ce qui concerne les composantes aux valeurs propres plus petites, ainsi qu'en ce qui concerne l'ordre de ces composantes, en particulier aprês rotation, lorsque les valeurs propres en cause sont très voisines. Ainsi que d'autres auteurs l'ont observé, les composantes de plus grandes valeurs propres ne manifestent pas nécessairement des différences interpopulationnelles plus élevées. Il y a cependant une absence d'universalité dans l'ordre des composantes et dans la structure des composantes qui présentent de grandes différences interpopulationnelles.