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Anthropometric Variation in the Yanadi: population structure and sex differences

Anthropometric variation and sex differences were investigated among the Yanadi tribe, who live in different regions and show differences in population structure variables and form regional breeding populations. In case of within population variation in anthropometric characters, both males and females show greater variation in a few specific characters (e.g., HB, LL) and almost no variation in FB, but least variation in HL and NB in males and in ZB, LB in females and show sex differences. Overall, females showed greater variation in more number of characters than males. In case of between population variation a few traits show clinal trend between male-female comparisons. Each character shows a specific pattern (e.g., HB, ZB, EL, GB) which vary according to the spatial distribution of the regional populations. The curves also indicate least average differences corresponding to within regional homogeneity among males and females (e.g., HB, ECD, EB) and increasing differences with males and females of other regions. A comparison of anthropometric profiles of the five populations show significant sex differences in IY subpopulation. The three mainland subpopulations show wide morphological differentiation with two coastal subpopulations, who also differ in subsistence pattern and geographically isolated. A comparison of anthropometric profiles between males and females across five populations show positive association between P1, HF and P_2 populations, whereas significant negative association with CY and HF. The correllelographs based on the male-female comparisons also indicate greater morphological similarity between sexes in case of within regional population. They also show clinal changes of either decreasing or increasing trends of morphological variation between populations in association with spatial distribution and population structure differences. The results obtained are in agreement with the expectations from the population structure of the tribe.

Key Words: Settlement pattern, regional breeding population, anthropometric profile, total morphological differentiation, correlelograph.

The study of population affinities and the process of microevolution especially among subdivided populations are usually studied with reference to a battery of both qualitative and quantitative characters. Such studies attempt to infer overall differentiation by multivariate distance analysis and clustering techniques. Besides overall differentiation, variation in a few specific characters which are likely to be influenced by genetic and nongenetic factors are also studied for the study of microevolutionary investigation. A majority of these studies focus on genetic characters, but more often anthropometric, dermatoglyphic and other quantitative and qualitative characters are also studied. In this respect, anthropometric characters have the advantage of being influenced by multiple genetic loci and by nongenetic factors, which are mostly related to population structure variables and vary from population to population. Furthermore, the anthropometric characters ~~have the additional~~ advantage of studying both the overall morphological differentiation and (or) with specific reference to few anthropometric characters, especially those, which show significant differences due to the influence of population structure variables.

Previous studies on anthropometric variation have investigated the degree and pattern of differentiation and have demonstrated especially, the role of genetic and nongenetic effects of population structure and history etc. (Livingstone, 1969, 1972; Workman and Niswander, 1970; Friedlander et al., 1971, Spielman, 1973; Friedlander, 1975; Lees and Crawford, 1976). Several studies have demonstrated marked physical differentiation between isolated subpopulations, within ethnic groups, tribes and other breeding populations (Mahalonabis, Majumdar and Rao, 1941; Sanghvi, 1953; Majumdar and Rao, 1960; Karve and Malhotra, 1968; Das, 1985). Microevolutionary changes and the influence of cultural differences, e.g. mating pattern and isolation on anthropometric variation were also investigated by Oliver and Howells, 1956, 1957; Hiernaux, 1966; Das, 1981. A few other population studies have focused on intra and inter population variation in anthropometric traits and also on overall morphological variation in relation to factors such as migration, fusion-fission etc., (e.g., Spielman et al., 1973; Lees and Crawford, 1976; Lees and Relethford, 1982; Blangero, 1990; Vasulu, 1993). However studies dealing with the nature and extent of sex differences in morphology or metric characters in relation to population structure variables are very few. For example, studies among Amerindians have shown a greater intervillage variation in anthropometric characters among males than females. The study has also shown a greater within village morphological homogeneity between sexes than their counterparts in other villages (Spielman, 1973). Lees and Relethford (1982) have observed greater differentiation for most of the anthropometric variables especially among the female migrants. Similar such sex differences due to population structure variables were also investigated in Jirels of Nepal by William-Blangero and Blangero (1990), the multivariate statistical analysis of the data has revealed a greater variance in cranial measures among females (than males) in some villages. In continuation with the above studies this study attempts to relate anthropometric variation in males and females to population structure in the Yanadi, a tribe in transitional stage from hunting-gathering to agricultural stage, which differs from the above studies and might reveal variable pattern of differentiation due to its transitional stage.

Materials and Methods

Population

The Yanadi are concentrated in the southern districts of Andhra Pradesh, India. They live in small clusters of families (settlements) in different geographical regions of their distribution and are differentiated into subpopulations of diverse subsistence economy, ranging from hunting-gathering to incipient agricultural groups to urban slum dwellers as a result of exposure to different levels of geographical, cultural and environmental influences in different regions for decades. For example, on the islands, the tribe is in hunting-gathering stage, while in plateau and hill forest regions they are mostly casual and agricultural labourers, and a few are settled agriculturists.

The Yanadi live in settlements, the size and type vary in relation to their level of subsistence economy i.e., from about 15 in "neighborhood settlement" in Challa Yanadi in coastal region and the Yanadi on islands, to about 50 in "satellite settlements" among causal and agricultural labourers and to a maximum size of about 100 among settled agricultural section of the tribe in hillforest and plateau regions. In a region, in general, these three types of settlements form cluster of close marital network and form local regional breeding populations, which in genetic point of view represents the spatial distribution and extent of local gene pools. An account of the origin, subsistence levels and associated cultural differences, marriage pattern and the formation of local (regional) breeding populations were described in earlier publications (Vasulu, 1989). And more details on ethnography of the tribe can be found from Stuart (1891); Thurston and Rangachari (1901); and Raghavaiah (1962).

Data

Altogether 13 settlements located in coastal, insular, plateau and hillforest regions were selected for a detailed anthropological investigation. A detailed analysis on marital migration, geographical barriers between regional settlements (geographical barrier index - GBI), enodgamy-exogamy, marriage migration matrix, indicate the formation of five regional breeding populations (Vasulu, 1989). They are Challa Yanadis (CY), a separate endogamous section of the tribe and are gatherers, the insular Yanadi (IY) who live on islands, possibly their original habitat, depend on gathering and incipient agriculture. And the rest three breeding populations are located in the mainland, they are: P1, HF and P2. The details of 13 settlements and the corresponding five rgional breeding populations and further details can be found in earlier publications (Vasulu, 1989; Vasulu and Pal, 1989).

The data on Anthropometric measurements were collected by the author from all the available adults (about 65% of the total population) aged between 18 to 60 from both sexes for each of the 12 settlements with the objective to cover the entire settlement in a region. However no metric data could be obtained from settlement 09 PTR in hillforest region and only three females could be measured for metric data from settlement O6 ALD in P1 region.

A set of 14 measurements that are common to both sexes and are precise (Martin, 1928; Weiner and Lourie, 1981) were collected . They are: stature (HV), head length (HL), head breadth (HB), frontal breadth (FB), bizygomatic breadth (BZB), bigonial breadth (BGB), exter canthion diameter (ECD), inter canthion diameter (ICD), nasal length (NL), nasal breadth (NB), mouth length (ML), mouth breadth (MB), ear height (EH) and ear breadth (EB). The data include mostly the cephalometric measurements since these are moderately or highly heritable characters and are sensitive for population differentiation (Friedlander, 1975; Lees and Relethford, 1982). Since the size of the settlements are small and include all the adults, the anthropometric data considerably vary and invariably include related individuals. More details on the anthropometric data and analysis were described in earlier papers (Vasulu and Pal, 1989 and Vasulu, 1994).

Analysis

The results were preliminarily screened separately for men and women for inconsistent values. Individuals with a measurement showing a value more than four standard deviations different from the mean were discarded in the final analysis. The scrutiny revealed four outliers: one among males for stature, and three among females for biacromial breadth and head breadth, which have been excluded.

To investigate anthropometric variability, each anthropometric character was standardized with respect to over all mean and standard deviation of the total Yanadi population separately for males and females, so that it is possible to investigate both the variability between characters and sex differences together for within and between the five regional breeding populations. The same method was also extended for the investigation of overall morphological variability among males and females for within and between the five regional populations of the Yanadi tribe.

The analysis for within and between population variations were considered at two levels of study units: 1. to investigate overall morphological variability between populations and also 2. to investigate variation separately for each anthropometric character.

Spearman's rank correlation (γ_s) were calculated to test the significance of sex differences in anthropometric characters for within and between regions. Mean squared distance based on Penrose (1954) C^2H coefficient was computed for estimating the overall anthropometric distances between the regional populations. Analysis of variance technique based on the standardized data for the mean squared distance matrix according to Edward and Cavalli Sforza (1965) method was used for estimating the total variability due to within sex and between sex categories (Spielman, 1973). The same method was also applied to each anthropometric character, in which case, instead of distances, the mean squared difference were considered, which is similar to one way analysis of variance. The nature and type of the settlements among the Yanadi restricts the sample size and the practice of consanguineous marriages violates some of the statistical assumptions of random independency of the sample, which therefore, allows less confidence on some of the statistical levels of significance. However, as is often realized in biological analysis, the primary concern is focused on the pattern of variation than on testing for its statistical significance (e.g., Spielman et al., 1973; Lees and Relethford, 1982).

The results of the analysis were presented separately for two levels of study units. a. variation in each anthropometric characters and b. anthropometric profiles depicting overall morphological differentiation of the five regional populations. Within each level the results are discussed for within and between populations (i.e. within sex and between sex comparisons) and correlations to test the significance of male-female differences in metric characters. These are presented both by Tables and graphic representations. However, the analysis of variance tables are presented for total anthropometric variability.

Study Hypothesis

The population structure variables especially breeding isolation, admixture rate (m), surname migration index (SMI), surname identity (Sii) and effective number of surnames (NeS) of the five regional breeding populations of the Yanadi tribe are given in Table 1. Based on the above population structure variables the following hypotheses can be raised with regard to pattern of anthropometric variation between the Yanadi population. First, corresponding to the pattern observed in endogamy and admixture rate, it is expected that the Yanadi should show a greater anthropometric homogeneity between P1, HF and P2 when compared to both CY and IY populations. Since the Yanadi marriage is patrilocal, a cultural practice where females are contracted from a wider area than males, so that the females are expected to show relatively greater within regional metric variation than their husbands. Or otherwise, in terms of between population comparison there will be greater anthropometric variability between males and than among females. Furthermore, within a region, both males and females more or less share common genetic endowment, the consequence of this situation will lead to within morphological homogeneity between sexes than when compared to their counterparts in other regions. The following analyses and results are aimed to investigate the above expectations with regard to population structure and anthropometric variation in the Yanadi tribe.

Results

1. Sex differences in anthropometric characters

TABLE 1 - Population structure variables among the regional populations of the Yanadi.

Regional Population	Admixture	M.M.D. rate (m)	S.M.I.	Sii	Nes	'f'	I
CY	—	10.86	17.0	0.0898	11.13	0.028	0.904
IY	—	12.02	2.5	0.1427	7.01	0.044	0.753
P1	1.2 + 0.8	15.81	38.3	0.0703	14.22	0.029	1.258
HF	2.4 + 0.8	24.79	11.8	0.0517	19.34	0.038	0.567
P2	0.3 + 0.3	18.20	24.8	0.0605	16.53	0.042	0.443

M.M.D.: Mean marital distance; S.M.I.: Surname migration index;
Sii: Within regional surname identity;
I: Opportunity for selection. 'f': Inbreeding coefficient.
Nes: Effective number of surnames.

Within population variation

The extent and magnitude of variation in anthropometric characters in males and females of the five Yanadi subpopulations are shown in Fig. 1 and Table 2. A general observation indicates at least two aspects: a) the pattern of variation differs for each character and b) they show wide sex differences between populations and between characters: to be specific, maximum variation is observed in HB (SD. 3.68) in males and in NB (SD. 3.38) in females, whereas the least variation is observed in HL (SD. 0.44) and in MT (SD. 0.65) in males and females respectively. In general, females show greater variability (S.D. > 1.60) in more number of characters (8) than males (6). Out of 14 characters three characters show significant association between sexes. These show a positive association in HB, EB ($rs = 1.0$, $p<0.01$) and MB ($rs= 0.9 < 0.05$) and an insignificant negative association in HL ($rs = -0.6$, $p> 0.05$). Whereas there is no association in other 10 characters (e.g., $rs = 0$, for HV, NB)

TABLE 2 - Anthropometric variability in males and females among the Yanadi.

Character	Variability (S.D.) Male	Variability (S.D.) Female	Sex difference Correlation (rank - r)
HV	1.76	1.44	0
HL	0.44	1.25	-0.60
HB	3.68	2.61	1.00@
FB	1.37	1.11	0.10
ZB	1.31	0.89	0.10
GB	1.38	2.79	0.10
ECD	1.79	1.62	0.50
ICD	1.79	1.89	0.30
NL	1.67	1.41	0.70
NB	0.78	3.38	0
MB	1.93	2.41	0.90*
MT	1.57	0.65	0.30
EH	1.15	1.64	0.40
EB	1.33	1.83	1.00@

@: P, 0.01 *= P, 0.05

Between population variation

Sex differences in anthropometric characters in case of both within and between five Yanadi regional populations are shown in Fig. 2(a). Out of a total of 25 pairs of male-female differences between the five populations, the five (marked in square and circle in the figure) represent within regional sex variation and the rest 20 combinations represent between regions. The noteworthy aspect of the diagram is that each character shows a distinct pattern of variation. There is a consistency in the pattern of anthropometric differentiation between populations especially in case of pair wise combination with respect to CY, IY and three mainland populations P1, HF, P2. These trends indicate possible association between anthropometric variation and spatial distribution and differences in population structure variables. To be specific, the figure shows a clear tendency of either decreasing or increasing mean differences, the magnitude of which greatly differ with the location and differences in subsistence pattern of the five regional populations. The differences are larger for the pairwise comparisons of the two preagricultural populations (CY and IY) than with the three mainland populations of P1, HF, P2. These can be noticed in the diagram, where the metric curves show (peak) maximum differences, especially seen in case of HB, ZB, EH, GB and to a certain extent in HL. But such systematic changes are however, not observed in case of NB, MT, NL, etc. Of all the characters, three traits: HB, NB, GB (mean 1.36, 0.37 and SD 4.06, 3.15, 3.05 respectively) show the maximum variation whereas HL, ZB, MT, NL, EH are least variable (SD 1.7 to 1.9).

Is there a tendency of regional bisexual homogeneity in metric characters? In case there is similarity between sexes within a local breeding population among the Yanadi, then the analysis is expected show least average metric differences corresponding to the five specific within regional sex-pair combinations corresponding to the five regional populations. To be specific, the metric curves are expected to show "bottleneck" shape corresponding to the least average differences for the five cases of within regional sex differences. This can be noticed (Fig. 2(a)) in case of HB and to a certain extent in ICD, HV, GB, though it is not consistent for all the five populations nor uniform for all the characters. Overall, out of 70 such cases for 14 characters, the least within regional mean sex differences are observed in 15 (21.4%) cases only.

A comparison of male-female differences in 14 metric characters between the five Yanadi populations are shown in Fig. 2(b). A wide sexual variation is observed in three characters: NB, GB and ZB. Males show the maximum variability in HB (SD 3.55), whereas females are more variable in NB (SD 4.36). Overall females show greater differentiation in 9 characters (64.3%) whereas males show in 5 characters (35.7%). Is there an association between the within sex pair combinations of male and female variability?. The rank correlations (Table 3) suggest significant positive association in seven characters HB, NL, EB, ($p < 0.01$) and in HV, ECD, ICD and MB ($r^s = 0.60$, 0.73, 0.74, 0.63 and $p < 0.05$). However two characters show the opposite trend of significant negative association: HL ($rs = -0.78$, $p < 0.01$) and ZB ($rs = -0.55$, $p < 0.05$). Whereas the rest few characters (FB, GB, MT, EH and NB) show poor correspondence between the like sex-pair comparisons of the corresponding five populations of the tribe.

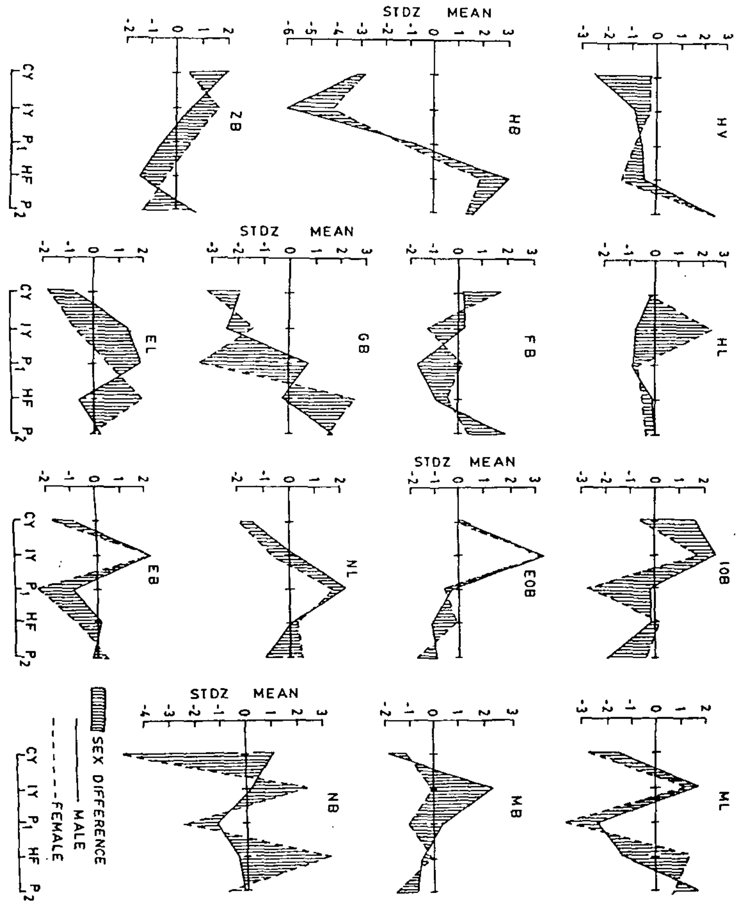

Fig. 1 The extent and magnitude of variation in anthropometric characters in males and females among the Yanadi.

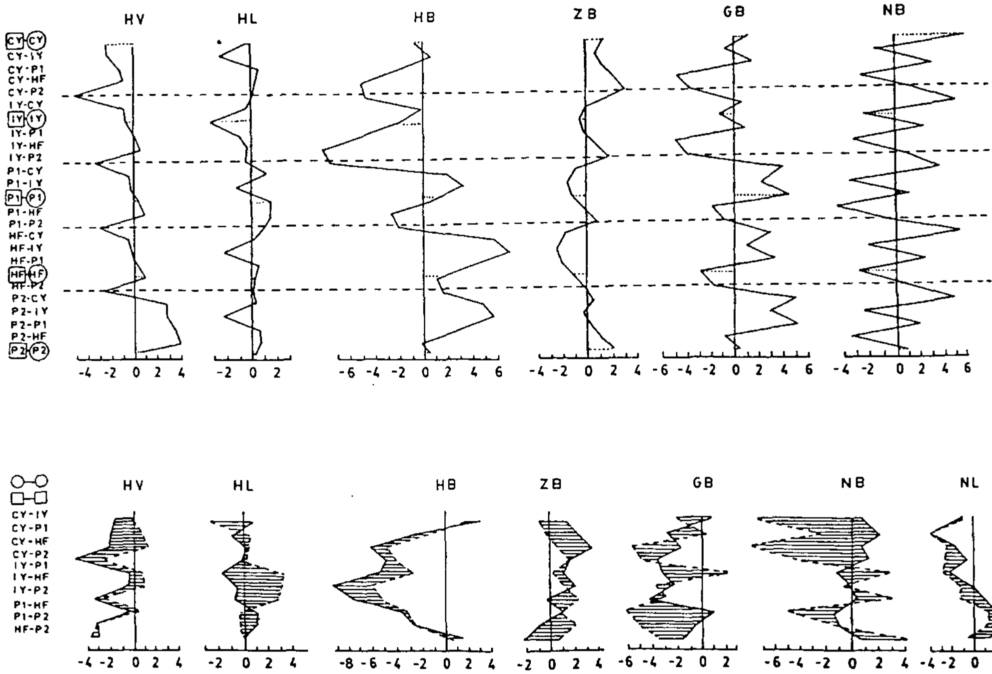

Fig.2 (a,b) Between and within sex variability in anthropometric characters among the Yanadi.

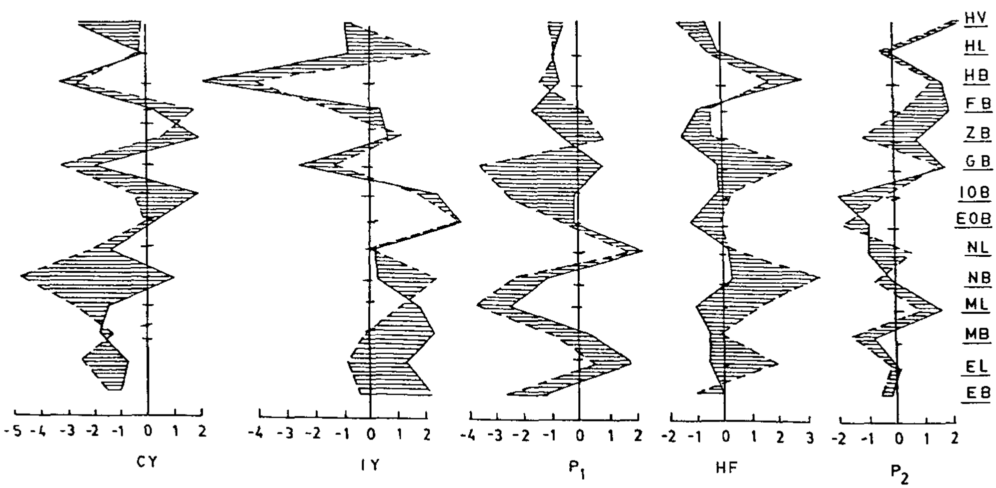

Fig.3 Anthropometric profiles for males(——) and females (------) of the five Yanadi populations.

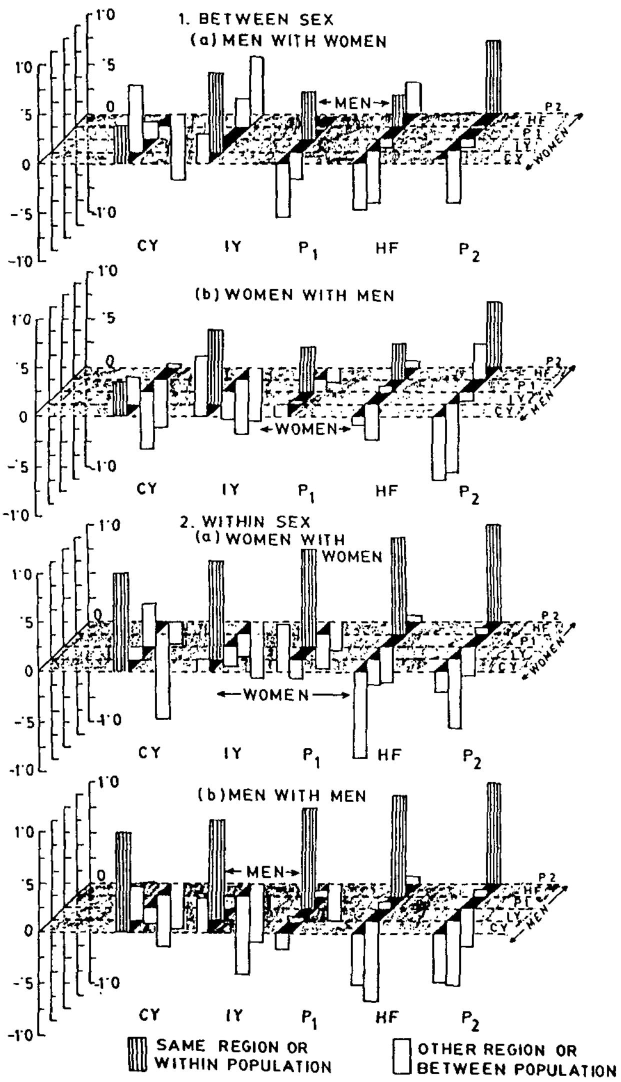

Fig.4 Correlographs for anthropometric characters among the Yanadis: 1. Between sex, 2. Within sex (between populations)

TABLE 3 - Overall anthropometric variability between and within sex category among the regional populations of the Yanadi.

Trait	Between sex Male-Female Mean	Between sex Male-Female S.D.	Within sex Male-Male Mean	Within sex Male-Male S.D.	Within sex Female-Female Mean	Within sex Female-Female S.D.	Rank correlation
HV	-0.242	2.101	-2.024	1.450	-0.795	1.879	0.600*
HL	-0.088	1.279	-0.172	0.861	0.558	1.683	-0.787@
HB	1.359	4.061	-3.808	3.550	-2.887	2.314	0.951@
FB	-0.137	1.619	-0.387	1.909	0.337	1.528	0.127
ZB	0.074	1.448	0.881	1.625	0.948	0.844	-0.551*
GB	0.365	3.152	-1.931	1.640	-2.971	3.222	-0.442
ECD	0.715	2.323	2.076	1.470	0.185	2.289	0.733*
ICD	0.098	2.376	1.351	2.146	1.305	2.303	0.745*
NL	0.305	1.822	0.211	1.987	-1.178	1.610	0.939@
NB	0.367	3.148	0.144	1.086	-1.813	4.356	-0.369
MB	0.285	2.838	-0.643	2.671	-1.457	3.078	0.636*
MT	0.113	1.763	0.132	2.231	-1.190	1.802	0.152
EH	0.626	1.931	0.017	1.677	-1.485	1.776	0.369
EB	0.659	2.153	0.119	1.882	-0.235	2.585	0.793@

@: P < 0.01 * : P <0.05

TABLE 4 - Within sex anthropometric variability between the regional populations of the Yanadi.

	Male-Male Mean	Male-Male S.D.	Female-Female Mean	Female-Female S.D.	Rank correlation
1. Within population					
CY-CY		1.52		1.65	0.419
IY-IY		2.34		1.94	0.566*
P1-P1		1.24		1.57	0.448*
HF-HF		1.02		1.38	0.316
P2-P2		1.27		1.15	0.478*
2. Between Population					
CY-IY	-0.971	2.003	-1.827	2.404	0.286
CY-P1	-0.213	2.102	-0.290	1.701	0.513*
CY-HF	-0.410	2.218	-1.983	2.900	0.395
CY-P2	-0.025	2.406	-1.766	2.144	0.645@
IY-P1	0.302	2.766	1.537	2.706	0.588*
IY-HF	0.561	3.184	-0.156	2.624	0.566*
IY-P2	-0.051	3.261	0.061	2.785	0.513*
P1-HF	0.069	1.559	-1.695	2.421	0.422
P1-P2	-0.545	2.134	-1.476	2.151	0.395
HF-P2	-0.615	1.567	0.195	1.767	0.084

@: p < 0.01 *: p < 0.05

TABLE 5 - Total Variability in Anthropometric characters due to withinsex and between sex contributions in the Yanadi regional populations.

Trait	Within sex (W.S.)				Between sex (B.S.)				Total variability		
	Male M.S.D.	Male T.C.	Female M.S.D.	Female T.C.	Same region M.S.D.	Same region T.C.	Between region M.S.D.	Between region T.C.	W.S.	B.S.	Total
HV	6.19	61.91	4.16	41.65	1.26	6.34	4.98	99.67	103.56	106.04	209.6
HL	0.71	7.71	3.14	31.42	2.52	12.61	1.34	26.70	39.13	145.35	184.5
HB	27.13	271.34	13.69	136.90	1.14	5.69	19.60	392.00	408.24	397.72	805.9
FB	3.79	37.96	2.45	24.50	2.04	10.17	2.64	52.76	62.46	62. 93	125.4
ZB	3.42	34.18	1.61	16.09	1.78	9.89	2.07	41.48	50.27	50.37	100.6
GB	6.43	64.32	19.21	192.11	6.02	30.12	9.67	193.57	256.43	236.69	480.1
ECD	6.45	64.52	5.27	52.75	3.22	16.07	5.69	113.97	117.27	130.04	247.3
ICD	6.43	64.28	7.01	70.08	0.42	2.09	6.67	133.97	134.63	135.52	269.9
NL	3.99	39.96	3.98	39.79	0.64	3.18	3.83	76.54	79.75	79.72	159.5
NB	1.19	11.99	22.26	222.61	9.76	48.78	9.46	189.19	234.60	237.97	472.6
MB	7.55	75.48	11.59	115.96	1.99	9.99	9.17	183.49	191.44	193.48	384.9
MT	4.99	49.94	2.43	24.26	2.77	13.86	3.04	60.75	74.20	74.61	148.8
EH	2.81	28.13	5.36	53.62	3.21	16.03	3.69	73.89	81.75	89.92	171.7
EB	3.56	35.55	6.74	67.41	1.53	7.67	5.20	104.06	102.96	117.73	220.7

M.S.D.: Mean Square Distance

TABLE 6 - Total Anthropometric variability due to within and between sex populations among the Yanadi.

Source	Mean square distance	No. of terms	Total contribution
Like sex			
Male-Male	2.320	10	23.204
Female-Female	7.522	10	75.222
Total			98.426
Between sex			
Same region	2.736	5	13.681
Between region	6.175	20	123.500
Total			137.181
Total variability	235.607		

2. Anthropometric profile: sex differences in morphology

Within population variation

The anthropometric profiles of males and females of the respective five populations of the Yanadi tribe are shown in Fig. 3 and Table 4. In general, both CY and IY show greater morphological variability than P1, HF and P2. The morphological profiles of male and female are similar for a majority of anthropometric characters except for NB (e.g., in CY and IY) and GB (in case of P1 and HF) where females show greater variability than males. Of the five populations, IY, P1 and P2 populations show significant morphological similarity between sexes ($rs = 0.56$, $p < 0.05$).

In only two populations (CY and HF) the magnitude of morphological similarity of males and females with other regional populations do not attain statistical significance.

Between population variation

The male-female differences in anthropometric profiles were investigated separately for both within and between populations (not presented). Similar to Fig. 2(a), there are 25 pairs of male-female combinations between the five regional populations: the five diagonal morphological profiles represent within regional variation in morphology and rest 20 offdiagonal figures represent between regions. In general the IY (male) population shows wide differences with P1, HF and P2 (female) populations. The figure also shows a trend of apparent increase of variability in case of both CY and IY males with the females of P1, HF and P2. This implies systematic changes in morphology in association with the spatial distribution and subsistence difference of the Yanadi populations.

Is there a morphological homogeneity between males and females of a local breeding population? A comparison suggest the least overall within morphological variability between sexes in case of both IY and P1 only (SD= 1.60 and 1.44). And this is not true in the rest three populations. But such morphological homogeneity was observed between offdiagonal figures: for example, the male populations of CY, HF and P2 show least variability with females of IY, P2 and HF respectively. The rank correlations between offdiagonal figures show significant ($p < 0.01$) dissimilarity between male-female pairwise combinations in case of CY and HF (rs = -0.79), IY and P1 (rs = -0.73) and for P1 and P2 (rs = -0.78).

The overall anthropometric differentiation in case of within sex category (male-male and female-female combinations) also show similar trends as was observed in case of between sex category (Table 4). For example, a greater variability was observed in case of male-male morphological differences of IY-HF (SD = 3.18). In case of females greater variability is seen in CY-HF (SD= 2.9), IY-P2 (SD= 2.78) and IY-P1 (SD = 2.71). The figure shows least sex differences in case of P1-HF and HF-P2 males (SD = 1.56) and in HF-P2 and CY-P1 females (SD=1.72). Is the two categories of within sex pair combinations show morphological similarity? The rank correlations suggest significant anthropometric homogeneity in case of CY-P2 (rs = 0.64, $p < 0.01$), CY-P1, IY-P1, IY-HF and IY-P2 (rs = 0.51, 0.59, O.56, $p < 0.05$) populations. And interestingly, the three mainland populations (P1, HF and P2) hardly show any association between the like sex-pair combinations of HF and P2 populations.

3. Total Morphological Variability

Variability in anthropometric characters

The results of the different pairwise combinations of male-female differences in 14 anthropometric characters for both within and between regions are given in Table 5. The table represent the summary figures of the matrices of male-female differences for each character. The higher values observed under the total contribution in the four categories indicate high variability of the characters that correspond to the wide deviations observed in Figs. 2 and 3.

In within sex category males show wide variability in HB and least in HL and NB and in case of females it is observed in NB, GB, HB, MB and least in ZB, MT. Males show greater variability in at least six characters (e.g. in ZB, MT, HB etc.).

In case of between sex category, the males and females of the same region show the least mean differences in 12 metric characters than when compared to between regions. For example, it is nearly 17 and 16 times larger for HB and FOB. It is about 14 times in three characters HV, EB, MB and in other seven characters it is nearly twice the value to the between sex category. The two notable exceptions are HL, NB, where the between sex category shows higher values than within sex. The most variable characters in case of within region are NB, GB, EH, ECD and least variable are ICD and NL. And in case of between regions the Yanadi show greater variability in seven characters (HB, GB, MB, ECD, ICD, EB) and least in HL and ZB. The pattern of variation is almost same in case of both within and between regions as was observed in the previous section. In case of total variability both the within and between sex categories show equal contribution to total metric variability in almost all the characters, except for HL, GB and EB, where the cross, sex values are 3.7, 0.87 and 1.14 times greater than the within sex category. Overall, the most variable characters are HB, GB and LL and the least are ZB and FB.

Overall anthropometric variability

Table 6 shows the total anthropometric variability partitioned into two components: within sex and between sex. In case of within sex category, the female contribution to total morphological variability is about three times larger than the value of males contribution. This suggest a greater morphological variability among females. Similarly in case of between category the total contribution of within regional sex variability is nine times less than between regional variability. This suggests that men and women within a region are more similar in their anthropometric profiles than their counterparts in other regions.

Association between sexes

The extent of correspondence of within sex and between sex variability in overall anthropometric characters of the five populations of the tribe are shown in correlographs (Fig. 4). The shaded area in the figure represents males and females of the respective five regions. Almost all the within regional men-women correlations are the highest and the values are significant in case of IY, P2 and P1 populations, suggesting within regional morphological similarity between sexes. However, there are two exceptions where interregional morphological similarity is not noticed, especially CY females with IY males and HF females with P2 males. In general, the correlellographs show a systematic increasing or decreasing trend of correlations in association with the spatial distribution of the five Yanadi populations. For example, the correlations decreases in case of CY and IY females with other regional males (of CY to P2), and in contrast the correlations gradually increase in case of HF and P2 females with other males (CY to P2). However, in case of P1 females the trend is not apparent. In case of within sex category (i.e. male-male and female-female comparisons) a significant negative association were observed for females between CY and HF populations and for males in case of IY-HF and CY-P2 comparisons.

Discussion

The Yanadi study shows sexual dimorphism and differential variability with respect to a few specific characters between the five regional breeding populations. What explanation can one seek to account for the wide morphological variability that was observed especially with respect to few specific characters and little variation in other characters? Heirnaux (1972), for a similar observation had indicated, rather a generalization, that human populations differ in time and space, a few change rapidly due to situations of their culture and environment. Whereas others have put forth a more directive influence of specific factors. For example, despite environmental influences, a greater possibility of genetic influence on some specific anthropometric characters have been reported by Spielman et al. (1973) among Yanomama Indians, and Lees and Relethford (1982) among Ireland population. Some of the characters included in the study show high heritability estimates (e.g. 0.59 for HL, 0.72 for HB, 0.61 and 0.60 for FB and ZB, 0.71, 0.76, 0.75 for GB, NL and EL, based on Clark, 1956). Since the agricultural way of life of the Yanadi tribe in HF and P2 populations is a recent phenomena of about 2 decades, and it may not be a important factor to cause significant morphological differences. Therefore the observed significant differences in metric characters, at least to an extent could be attributed primarily, due to genetic factors.

Overall, males show a greater regional anthropometric variability than females. This was similar to the Yanomama study, where they also showed significant intervillage variation among males. The greater intervillage dermatoglyphic variation among males (Rothhammer et al., 1973) has been explained to the possible effect of patrilocal marriage system. In a patrilocal marriage system, the females come from diverse origin than males, which at intervillage level comparison implies a greater variability between males than females. The marriage among the Yanadi is patrilocal and often consanguineous. Generally the brothers live together in separate settlements at one location whereas their wives come from neighborhood settlements (Vasulu, 1989). This implies greater within settlement homogeneity among males and consequently greater interregional variability. This gains credence from the results obtained from the size and shape components of anthropometric differences and morphological differentiation and the results obtained in dermatoglyphic data (Vasulu, 1991, 1994) and this supports the Amerindian experience. These results suggests that it might be a common phenomena in other populations governed by similar population structure and circumstances of survival.

One more explanation for the observed sex differences in anthropometric characters and morphology that could be invoked from the literature is the observation that males are more influenced by environmental factors (e.g., Hall and MacNair (1972), Hall 1978), whereas females are more adaptive and show less perturbations to environmental disturbations due to canalization, which might influence the morphological profiles differently among males and females. The consequence of the canalization is less differentiation and variability among females. But how for this explanation is valid for the present study is difficult, the detailed analysis is beyond the scope of the paper.

There is a remarkable least within regional mean differences in at least 12 anthropometric characters between sexes when compared to between regions. Since in a regional endogamous population both males and females share a common environment and share to a great extent, common genetic endowment, it is expected that they show a greater homogeneity in several of their biological characters. This can be explained by two possible ways: regional endogamy and inbreeding. Among the Yanadis, the regional populations show high rates (80%) of endogamy, inbreeding (0.04), spatial isolation and within regional environmental homogeneity (Vasulu, 1989). The cumulative effect of these two is expected to result in within-regional metric homogeneity between sexes.

The anthropometric differences between populations show a trend of increasing or decreasing mean differences in a few specific metric characters (e.g. HB, ZB, EL, GB, HL) from CY to P2 populations. Similar trends of variability is also observed in anthropometric profiles. For example, male population of CY and IY show an increasing mean differences with the females of P1, HF, P2 populations. In contrast, P1, HF, P2 males show a decreasing trend of metric differences with female populations of P1, HF, P2. These systematic (clinal) changes are also observed in case of within sex and between sex correlations for overall anthropometric characters. For example, the CY and IY females show decreasing correlations towards the male populations from CY to P2 and in case of HF and P2 females. The correlation increases towards the male populations of CY to P2. These trends suggest a significant metric variation in relation to the spatial dustribution and population structure of the Yanadi population. The population relatively farthest located reflect least metric similarity. Possibly isolation by distance model of population structure may deem appropriate in predicting the genetic variability among the Yanadi.

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