Evaluation of Effects of High Natural Background Radiation On Some Genetic Traits in the Inhabitants of Monazite Belt in Kerala, India*

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ABSTRACT

With a view to assess the possible long-term effects of chronic low-level radiation on human quantitative characters, several dermatoglyphic parameters were studied among the inhabitants of monazite belt in Kerala, India. Previous investigators have estimated that these populations are exposed to 87r per 30 years. Dermatoglyphic data from 74 males native to this area were compared with those from 72 ethnically comparable males native to another area exposed to near-normal levels (6r per 30 years) of background radiation. All the six quantitative characters so studied showed lower variance among the exposed population as compared to the "controls". Two possible interpretations have been considered to account for this somewhat puzzling finding: (1) The exposed population may have originated from a small group of possibly related individuals; then subsequent expansion of the population may have occurred in the absence of significant additional immigration. (2) The effects of chronic low level radiation may not be the same as those of high acute doses; the former may sometimes decrease rather than increase variance of quantitative traits.

There is an area of high natural background radiation on the west coast of India, in the state of Kerala. In a search for genetic effects of high natural radioactivity Grüneberg, et al. (1966) surveyed a rat population living in this area with respect to several qualitative and quantitative traits but were unable to detect any effect attributable to background radiation.

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The present study was undertaken to detect possible effects of such background radiation on several quantitative characters in a human population which has existed in this area for over a thousand years. The characters chosen were all dermatoglyphic parameters which, besides being easy to collect, are known to be extremely sensitive to numerical and structural changes in the karyotype (Penrose, 1968a).

Materials and Methods

High Background Radiation Area

The highest levels of known natural background radiation exist in some parts of Kerala and Tamil Nadu States on the west coast of India (Gopal Ayengar, 1957; Bharatwal and Vaze, 1958; WHO, 1959). The radioactivity arises from the presence of varying amounts of monazite which contains 8-10.5% thorium with long half life. This element decays with the emission of *alpha, beta* and *gamma*-rays. However, most of the genetic effects are expected to result from the penetrating *gamma*-rays and not from the short range *alpha* and *beta*-radiation.

Monazite sand mixed with ordinary sand is deposited all along the Malabar Coast. However, there are two areas which are particularly rich in monazite: (1) Manavalakurichi near Cape Comorin in Tamil Nadu and (2) Kayamkulum-Neendakara strip near Quilon in Kerala (Fig. 1). The present survey was confined to the latter area. It is located around the 9° North latitude and is bounded by the Arabian Sea to the west, backwaters to the east, Kayamkulum Lake to the north and Ashtamudi Lake to the south. A strip about 6 km long, Vellanathuruthu-Puthenthura, was selected as the high background radiation area.

The radioactivity varies from one location to another within this high radiation area. It increases as one proceeds from east to west and from north to south. The range of *gamma*-radiation, as measured three feet above ground level, is from 0.03 to 1.3 mr/hr with a mean of 0.3276 mr/hr or about 2.9 r/yr (for details see Grüneberg, et al., 1966). Taking 30 years as the reproductive midpoint of an individual the inhabitants would have received a chronic dose of up to 87r stretched over this period. (The average dose on a worldwide basis is about 3r/30 years.)

Control Area

Poonthura near Trivandrum was chosen as the control area. In this area the radioactivity is of the order of about 6r/30 years (Patterson and Wallace, 1963). Hence, the ratio of radioactivity between the two

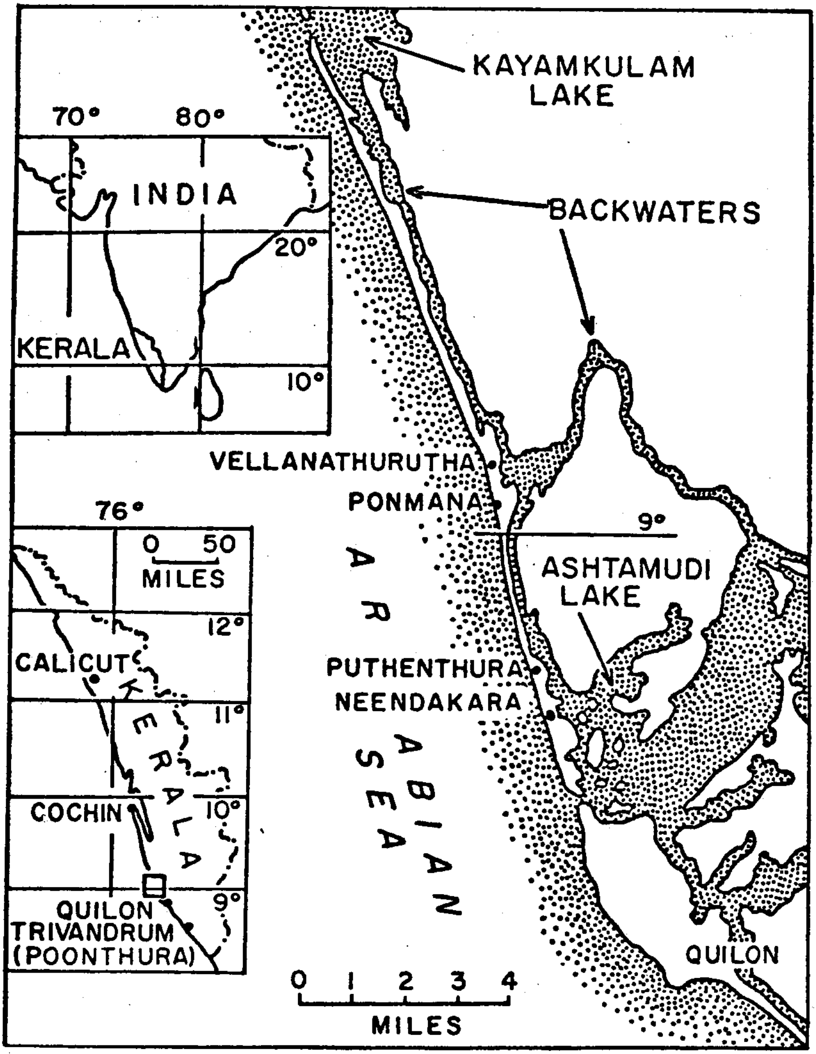

FIG. 1. Map showing the experimental and the control areas. Experimental area of high background radiation is about 8 km north of Quilon. It is about a 22.5 km long strip extending from Kayamkulum Lake in the north to the Ashtamudi Lake in the south, and is bounded by the Arabian Sea on the west and backwaters on the east. Control area was selected near Trivandrum. Hatched areas represent water. (Modified after Grüneberg, *et al.*, 1966.)

areas is about 14.5. The high radiation area and the control area are about 120 km apart.

Past History and Geography of the Area

The Malabar Coast of India was the center of international trade long before the Christian era, and the city of Quilon, a few miles south of the strip, was once an important port of call for Arabs and Chinese.

It is generally believed that the Arayas or Mukkuvas originally came from Ceylon (Menon, 1911). Although mention about Mukkuvas on the west coast dates back to the beginning of the fifteenth century (Cortesão, 1944; Churchill and Churchill, 1704), Weiss (in Grüneberg, et al., 1966) after a detailed historical survey, has suggested that these people may have been living in this area for the last one thousand years. In other words, the Arayas have lived in this area for at least 30 generations, and probably more.

There is a custom of close marriages among the Arayas. Marco Polo, the great Venetian traveller, who visited the west coast of India around the year 1275, talks about cousin marriages among the people of this area (Aiya, 1906). It therefore appears that in this region the custom of marriages among close relatives has had a long history.

People

A group of fishermen, called Arayas, also known as Mukkuvas, are located all along the west coast of Kerala. They belong to three religious sects: Hindus, Muslims and Christians. The present study was confined to the Hindu Arayas only. Hindu Arayas are only one of the numerous endogamous groups inhabiting the state of Kerala; because of strong taboos they do not intermarry with other groups. Also, close marriages are preferred; about 15% of the marriages are between first cousins.

Although both the exposed and the control subjects belong to the same endogamous group the chances of gene flow between them are negligible. Most of the marriages are arranged locally; no marriages were discovered to have taken place between parties within and outside of the high radiation area, and only rarely (in the control area) outside a radius of 32 km. The control area is about 120 km away from the experimental area.

Both the exposed and the control subjects live under very similar conditions. Their living quarters are mostly thatched huts built on the sandy beaches. Their food habits also appear to be very similar.

Sampling

Sampling was done in the first week of June, 1970, when the rainy season (monsoon) was just beginning. As this season is not good for fishing, most of the people of the Araya community were easily available for study.

Only male subjects were surveyed. In the high radiation area the samples were taken from three locations, whereas in the control area only one location was used. The sampling procedure was as follows. A table was set up at a convenient spot in each of the locations, and the passersby were requested for cooperation. Those who agreed were included in the sample. Name, address, names of parents, and addresses of parents before their marriage were recorded for each subject. All efforts were made to avoid close relatives (sibs, parents and children of a subject). Age range of the exposed sample was 16 to 68 years whereas that of the control was 16 to 65 years. The number of individuals drawn from each of the locations is given in Table 1. In all 74 individuals were studied from the experimental area and 72 from the control.

Traits Studied

The dermatoglyphic characters studied included total finger ridge count, *a-b* ridge count, pattern intensity index, main-line index (D + A), *c-t* distance (using the proximal t), and *atd* angle (using the most lateral a triradius, the most proximal t triradius and the most medial d triradius). For a detailed description of these traits see Cummins and Midlo, 1943; Penrose, 1968b.

Table 1

Number of Males Surveyed

Village	Sample Size	Total
Exposed		
Vellanathuruthu	19	74
Ponmana	11	
Puthenthura	44	
Control		
Poonthura	72	72

Genetic Evaluation of Traits Studied

Total finger ridge count is one of the most thoroughly studied quantitative characters in man. The familial correlations for this trait are in remarkable agreement with the theoretical values for perfectly additive genes. A correlation coefficient of 0.95 has been observed for monozygotic twins, indicating that the genetic component of the variance of this trait is approximately 95% of the total whereas the environmental component is only 5% (Holt, 1968). It is therefore obvious that for studies such as those reported here, this character is preferable to other quantitative characters like height.

Next to total finger ridge count in heritability, among the traits we have studied, probably come *a-b* ridge count, main-line index, pattern intensity index, *atd* angle and *c-t* distance in importance (Holt, 1968; Plato and Ahuja, unpub. data).

Method of Recording

Inked finger balls and palmar prints were recorded by the cotton T-method (Sharma, 1963). In order to keep uniformity in observations only the senior author was involved in scoring finger and palm prints.

Analysis of the Data

All the traits studied, except *c-t* distance, are age-independent. In the case of *c-t* distance, only individuals of 18 years and above were included on the assumption that ossification is largely complete by this age.

Due to one or another reason every trait mentioned above could not be recorded/deciphered in all the individuals. Thus, the number of individuals covered for each trait varies and has been given under Results. Analysis of variance was carried out for all the traits.

Results

The results are summarized in Table 2. The F-test was applied to test the hypothesis of equal variance in the two populations. The variance of the total finger ridge-count, *a-b* ridge count and main-line index in the exposed subjects are not significantly different at 5% level of confidence from the controls whereas those of the pattern intensity index, *c-t* distance and *atd* angle are significantly different. In all these

Table 2

Statistical Constants Pertaining to Some Quantitative Dermatoglyphic Traits

Trait		Exposed	Control	t† and F value
Total Finger Ridge-Count	No. of subjects	70	60	
	Mean ± S.E.	170.73 ± 4.42	179.62 ± 5.74	$t_{128} = 1.24$
	Variance	1367.97	1978.92	$F_{59,69} = 1.45$
a-b Ridge-Count	No. of subjects	66	57	
	Mean ± S.E.	71.21 ± 1.11	74.40 ± 1.31	$t_{121} = 1.87$
	Variance	80.91	98.32	$F_{56,65} = 1.22$
Main-Line Index	No. of subjects	68	62	
	Mean ± S.E.	16.53 ± 0.40	18.48 ± 0.48	$t_{128} = 3.16^{**}$
	Variance	10.64	14.25	$F_{61,67} = 1.34$
Pattern Intensity Index	No. of subjects	70	60	
	Mean ± S.E.	15.73 ± 0.38	15.57 ± 0.52	$t'_{128} = 0.25$
	Variance	10.20	16.49	$F_{59,69} = 1.62^{*}$
c-t Distance	No. of subjects	64	53	
	Mean ± S.E.	152.53 ± 1.73	145.38 ± 2.72	$t'_{115} = 2.20^{*}$
	Variance	191.21	392.12	$F_{52,63} = 2.05^{**}$
atd Angle	No. of subjects	71	55	
	Mean ± S.E.	76.68 ± 1.05	80.15 ± 1.77	$t'_{124} = 1.68$
	Variance	78.68	172.54	$F_{70,54} = 2.19^{**}$

† When F value is significant a modified t'-test has been used (Steel and Torrie, 1960).
* Significant at 5% level.
** Significant at 1% level.

six traits the variances are on the lower side in the exposed subjects as compared to the controls.

Means of total finger ridge count, *a-b* ridge count, pattern intensity index and *atd* angle in the exposed subjects were not significantly different at the 5% level from the controls, but those of the main-line index and *c-t* distance were different at the 5% level of confidence. In general, the means (in terms of our definition of characters) tend to be lower in the exposed subjects as compared to the controls except in the case of pattern intensity index where it is the other way around. Since the selective advantages of the traits studied are not known, it is hard to come to any conclusions based on the comparisons of the means.

Discussion

In the case of a quantitative trait an increased rate of mutation followed by recombination is expected to add to its variance. It is, however, interesting to note that among all the six quantitative traits studied, the variances are lower in the exposed subjects as compared to the controls despite the fact that the exposed subjects were selected from three locations whereas the controls came from a single area. This comparison of variances would, of course, be most striking if all the traits used were independent of each other, and therefore, correlation coefficients (r) were calculated for all possible combinations of parameters (Table 3). Total finger ridge count and pattern intensity index were highly correlated in both the sets and this was not unexpected, but the other correlations were relatively weak. There were, however, three discrepancies between the exposed and the control sets: (1) total finger ridge count and main-line index, (2) *a-b* ridge count and *atd* angle, and (3) *c-t* distance and *atd* angle. The values of r were significant in one of the two sets but not so in the other. An approximate test for statistical significance of the differences between the correlation coefficients of these three pairs of values was carried out as follows: the coefficients were first converted to Fisher's Z (Fisher and Yates, 1948) and a t test made using degrees of freedom as described by Dixon and Massey (1957, p. 124). They were found to be significant at the 5% level; we do not have any ready explanation for these differences. Taking an overall picture one can say that most of the traits are probably independent of each other except total finger ridge count and pattern intensity index.

Table 3

Coefficients of Correlation (r) *for All Possible Combinations of the Quantitative Parameters Used. The Values of* r *above the Diagonal Refer to the Exposed Population Whereas Those Below Refer to the Controls. Number of Pairs Are Given within Parenthesis. Significant Values of* r *Are Designated by An Asterisk*

	Total Finger Ridge Count	*a-b* Ridge Count	Main Line Index	Pattern Intensity Index	*c-t* Distance	*atd* Angle
Total Finger Ridge Count		0.0150 (63)	0.3356* (65)	0.7593* (70)	0.0105 (61)	−0.1331 (68)
a-b Ridge Count	0.1611 (52)		−0.1650 (66)	0.1086 (63)	−0.0749 (62)	0.6995* (66)
Main Line Index	−0.1886 (54)	−0.2078 (57)		0.1695 (65)	0.1347 (64)	−0.2005 (68)
Pattern Intensity Index	0.8295* (60)	−0.0626 (52)	0.0183 (54)		0.0042 (61)	−0.0781 (68)
c-t Distance	0.1140 (46)	0.1302 (50)	−0.1252 (53)	0.0762 (46)		−0.0181 (64)
atd Angle	−0.2174 (51)	0.1499 (51)	−0.0065 (55)	−0.0911 (51)	−0.8682* (47)	

Two possible explanations may be offered for the lower variances of the exposed population as compared to the controls.

The low variance in the exposed population might merely be a consequence of its having originated from a small group of people, who might have even been a group of relatives (founder effect). Further, one may conjecture that the exposed group has largely been a closed population with very little immigration for the last 30 or more generations. As mentioned previously, the measurements we present refer exclusively to members of a single endogamous group. This would imply, of course, that the control population traces back to a larger original group or else that it has not been protected from immigrants to the extent characteristic of the exposed population. Although reliable statistics about past populations are not available, the geographical location of the experimental and the control areas lends some indirect support to the above contention. The sample of the exposed population was drawn from a narrow strip of land (about 22.5 km long and 140-730 m wide) which is relatively isolated geographically. It is like an island, and is bounded by the Kayamkulum and Ashtamudi Lakes in the north and south, respectively, and by the Arabian Sea on the west and backwaters (18 to 275 m wide or more and infested with crocodiles until recently) on the east. Hence, initial population of this area might have been small. Although the southern tip of the strip is only 8 km away from the big city (Quilon) it is separated from it by Ashtamudi Lake which probably has restricted the movement of the people into the area. (In recent times a major highway has been constructed which passes through the southern tip of the strip. It is doubtful if it has materially affected the population structure of fishermen living in this area.) On the contrary, the control area has no geographical isolation as such and hence could have started with a larger population as compared with the high radiation area. Moreover, there is no geographical barrier between the control area and the nearest big city (Trivandrum), which is also located at a distance of about 8 km. In other words, this area is not protected against immigrants as much as the high radiation area.

The second possibility to be considered is that the lower variance is actually a consequence of the increased radiation. All reports of an increase in the variance of quantitative traits following radiation exposure deal with high acute doses (Clayton and Robertson, 1955; Buzzati-Traverso and Scossiroli, 1958; Yamada and Kitagawa, 1959; Scossiroli and Scossiroli, 1959; Buzzati-Traverso, 1960). Is it possible that the low chronic radiation has the opposite effect? Searle (1964), working with mice exposed to low chronic radiation, observed a lower divergence of minor skeletal variants in the exposed as compared to the control population. He explained his unexpected results by postulating a drastic change which may have occurred in one of the control lines. Later (1967), commenting on his earlier work, he suggested that more work was needed on the effect of low chronic radiation on quantitative traits before anything further could be said on this problem. It is conceivable that chronic low level radiation has a much greater direct phenotypic than genetic effect on development, and that a generally poor environment may tend to reduce variance, as observed, for example, by Scarr-Scalapatek (1971) with respect to variance of I.Q. in individuals living in poor environments. Similarly, Falconer and Latyszewski (1952) and Falconer (1960) observed that the within-litter variance in six week body weight of mice on a low plane of nutrition was lower than that on a high plane. Also, Professor William J. Libby (personal communication) has indicated that in the pine, *Pinus radiata,* overall variance is lower on moisture- or nutrient-deficient sites, as compared to that among plants growing in near optimal sites. We may therefore look upon the lower variance observed in our data as being the result of conceivably poor environmental conditions consequent to the background radiation.

Although no convincing effect of radioactivity was demonstrable on any of the characters studied, the findings of a consistent decrease in variance among the people living in high radiation areas raises several interesting questions. Further studies, involving larger numbers of individuals and a wide array of characters may answer these questions. Moreover, if the observed differences in variances are actually a result of restricted genetic variation among the ancestors of one of the populations, some of the traits studied may be useful as possible indicators of relative genetic heterogeneity in other populations.

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