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Cytogenetic Investigation in a Brazilian Population Living in an Area of High Natural Radioactivity

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INTRODUCTION

This paper presents a cytogenetic survey of the inhabitants from Guarapari, a small village on the coast of the state of Espirito Santo, Brazil, who live permanently exposed to high levels of radiation. The geological, physical, and radiochemical aspects of the survey in this area have been published [1–4].

Guarapari is a village of 12,000 inhabitants located on patches of black sand composed of ilmenite, rutile, and monazite. Monazite is a combination of rare-earth phosphates with 6% thorium and 0.3% uranium impurities. The beaches in the area contain 25%–30% monazite. External radiation levels within Guarapari range between 0.05 and 0.2 mR/hr, with peaks up to 0.6 mR/hr in houses where black sand has been used in the buildings and up to 2 mR/hr on some beaches. The average dose of 640 mR/year for the inhabitants was determined by a lithium fluoride dosimeter. The dosimeters, enclosed in medals to be hung from the neck, were distributed to about 500 persons [5, 6]. Attempts to detect above-normal body burdens of long-lived radionuclides by whole-body counting, measurements of thoron in breath, and radiochemical analysis of teeth and placentas were entirely negative. Thus this population, living in an abruptly changing radiation field, is exposed to external doses of 10–100 times the normal background level and to the possibility of internal contamination by radionuclides from the thorium and uranium series.

This survey was performed in order to detect possible biological effects of chronic natural radiation exposure.

MATERIALS AND METHODS

Chromosomes were studied by a modified version of the blood lymphocyte technique of Moorhead et al. [7]. Blood samples were collected in the field and within 24 hr were flown back to the laboratory where cultures were set. Colchicine was added 2 hr prior

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to the onset of fixation, which was started after 72 hr of incubation. Chromosome aberrations were scored according to standard criteria [8]. People with local residency of at least 8 years and a negative history of recent medical radiation exposure were chosen as blood donors. The control group was comprised of individuals from Saquarema, a village of similar socioeconomic level but with normal background radiation. The number of chromosome aberrations in the two groups were compared by means of a χ^2 test and a multivariate analysis.

The multiple regression was made using the chromosome findings as a dependent variable and the origin of the individual studied (Guarapari or control) as the independent variable. Some concomitant variables such as sex, age, age squared, and number of cells counted were included in the models to avoid confounding effects (for details see [9]).

RESULTS

The results of the cytogenetic study in 202 individuals from Guarapari and 147 from the control area are shown in table 1. The microscopic analysis was

TABLE 1

CYTOGENETIC SURVEY

	Guarapari	Control
No. subjects	202	147
No. cells	13.242	9.001
No. aneuploid cells	689	510
	(5.20)	(5.66)
Chromatid-type aberrations	404	328
	(3.05)	(3.64)
Chromosome-type aberrations:		
Deletions	133	77
	(1.00)	(0.85)
Dicentrics	15	6
	(0.11)	(0.06)
Rings	5	0
	(0.03)	...
Total no. breaks*	173	89
	(1.30)	(0.98)

NOTE.—Values in parentheses represent percentages of total number of cells analyzed.

* Scored as one break for deletions and two breaks for dicentrics and rings (see text).

performed in codified slides, and all aberrations were checked by at least two cytogeneticists. The number of aneuploid cells ($2n \neq 46$) and the chromatid-type aberrations were not considered as radiation induced. They are included in the table as culture technique controls. The total number of breaks refers to the breaks producing deletions (one for each deletion) and those producing rings and dicentrics (two for each ring or dicentric).

Table 2 shows the individual means for each of the cytogenetic variables analyzed. The maximum and minimum values, means and standard deviations of the cytogenetic data, and some population variables are shown in table 3. Finally, table 4 shows the results of the regression analysis performed. A significant positive correlation was found between the total number of breaks and place of residence (coded 0 if control and 1 if from Guarapari). The χ^2 test showed a significant difference in the total number of breaks ($P < .05$).

TABLE 2

INDIVIDUAL MEANS AND STANDARD DEVIATIONS FOR CYTOGENETIC DATA

	Guarapari	Control
No. cells	66.55 ± 22.75	61.23 ± 10.72
No. aneuploid cells	3.45 ± 3.81	3.46 ± 2.67
Chromatid aberrations	2.00 ± 2.54	2.23 ± 2.92
Deletions	0.65 ± 1.01	0.52 ± 0.90
Dicentrics	0.07 ± 0.28	0.04 ± 0.19
Rings	0.02 ± 0.15	0.00
Total no. breaks	0.85 ± 1.20	0.57 ± 0.93

DISCUSSION

The Guarapari population is exposed to a mean accumulated external radiation level about six times the normal background and to possible internal contamination by airborne natural radioactivity via the respiratory and digestive tracts.

The increase in the total number of chromosome breaks in the Guarapari population and the dependence of this variable (on an individual basis) on the place of residence of the study group may be interpreted as an effect of the natural radiation present in the monazite sand area. This interpretation is reinforced by our choice of a 72-hr rather than a 48-hr culture system, which should mean that some of the unstable aberrations would be lost in the first post-irradiation division. We hesitate, however, to interpret our results as an effect of higher external radiation levels. The high incidence of two-hit type aberrations suggests the existence of internally deposited sources of high linear energy transfer radiation emitters which could more efficiently induce this complex type of aberration.

Since all tests for contamination by long-lived radionuclides in the Guarapari inhabitants yielded negative results [6], our hypothesis is that they carry short-lived radionuclide body burdens by inhaling airborne thoron and thoron daughters [10]. In an area contaminated by thorium, the airborne radioactivity is due primarily to ^{220}Rn and its decay products, of which ^{212}Pb is the most suitable

TABLE 3

STATISTICAL PARAMETERS FROM GUARAPARI AND CONTROL POPULATIONS

	Maximum	Minimum	$\bar{X} \pm SD$
Age	68	8	29.50 ± 11.57
No. cells	228	35	65.73 ± 18.72
No. aneuploid cells	21	0	3.46 ± 3.36
Chromatid aberrations	23	0	2.09 ± 2.70
Deletions	7	0	0.60 ± 0.96
Dicentrics	2	0	0.06 ± 0.24
Rings	1	0	0.01 ± 0.11
Total no. breaks	7	0	0.73 ± 1.10

NOTE.—Includes data on 198 males and 151 females.

TABLE 4

REGRESSION ANALYSIS OF CYTOGENETIC VARIABLES ON ORIGIN OF POPULATION

Variable	Regression Coefficient (± SE)
No. aneuploid cells	−0.39 ± 0.31
Chromatid aberrations	−0.12 ± 0.31
Deletions	0.09 ± 0.11
Dicentrics	0.04 ± 0.03
Rings	0.01 ± 0.01
Total no. breaks*	0.23 ± 0.12

NOTE.—Code for origin of population: 0 = control; 1 = Guarapari.
* t test showed significance at $P < .05$.

indicator of the degree of contamination. The fact that most of the airborne ^{212}Pb activity in the atmosphere of monazite areas is found in aerosols with a count median diameter below 0.4 μm [11] and that a significant fraction of the inhaled ^{212}Pb is cleared from the lungs and fixed by the cellular fraction of the blood [12–14] is in strict conformity with the proposed hypothesis.

This hypothesis is further supported by our recent finding of a positive correlation between the levels of airborne ^{212}Pb and ^{212}Bi and the number of two-hit type aberrations in the workers of a monazite sand ore mill [11]. These workers are exposed to the same type of radiation as the Guarapari inhabitants, but in much higher doses, thus permitting the establishment of the correlation mentioned above. The negative results obtained on the whole-body count performed on the Guarapari inhabitants (usually about 2 days after they left the radioactive areas) may be explained by the disappearance of their temporary body burden with the effective half-life of ^{212}Pb.

The dose delivered to the blood cells after the inhalation of airborne ^{212}Pb and ^{212}Bi is currently under evaluation [15] in a group of thorium workers. The cytogenetic findings of this population should add important data to our hypothesis.

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