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Strontium-90 Levels in the Diets and Bones of Children

PROGRESS REPORT - 1964

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Introduction

The 1962-1963 Progress Report summarized data on Sr-90 levels in bones and diets of children in Argentina and attempted an estimation of strontium to calcium discrimination factors as a function of age.

This report gives emphasis to subjects for which little or no information was included in the former report, namely:

a) Stable strontium levels in bones and diets and discrimination factors worked out from these data.

(With stable strontium, equilibrium conditions are insured.)

b) Up-dating information on Sr-90 in children's diet and estimation of changes in the 1962-1963 period.

c) Strontium-90 levels in stillbirth bones.

New data on bone from children having lived in the "controlled environment" are not included in the report, as they are at present being processed together with the corresponding individual dietary information, and only the raw results from measurements are available.

Detailed discussion and references on the material presented in the report can be found in a C.N.E.A. report now in publication. This paper, which gives due acknowledgement to A.E.C. support, will be shortly submitted as a complement of the present Progress Report.

Natural Strontium in Bones and Diets

a) Experimental Procedures

1. Measurements

Measurements were carried out with a modified Philips PW-1051 spectrometer, using a LiF monochromator, a W anticathode and a thin X-ray NaI detector with the corresponding electronics. The work was performed with an evacuated difraction chamber and a primary beam produced by 40 Kvolt and 20 mA.

Samples were placed on holders with a 30 mm diameter window. The primary beam definition was excellent, with an area of 240 mm^2. The goniometer was automatically driven and counting recorded between 20 and 30^o. In our conditions strontium amounts are proportional to the 25.10^o peak intensity, background subtracted.

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2. Standards

The matrix was PO_4HCa purified in our laboratory, to which Sr was added as PO_4HSr in variable concentrations (from 10 to 5000 ppm). Powders were reduced to 100-150 mesh and homogenized during 4 hours in a rotating blender. Several checks showed that measurements of different portions of the mixture were within the counting standard deviation.

3. Sample Preparation and Measurement

Samples were ashed and dissolved in nitric acid, and then insoluble phosphates were precipitated and dried and a graded powder prepared.

Strontium content in the phosphate powder is determined with the technique described; then the sample is redissolved, a calibrated amount of Sr is added and after reprecipitation the measurement is carried out again. This internal standard procedure has proved to be of importance in reducing interfering effects (blank effect, auto-absorption, etc.).

b) Natural Strontium in Bone

The results correspond to samples obtained in the Sr-90 survey during 1963.

Table I shows the stable strontium levels in stillbirths; standard deviation in the Sr/Ca results is estimated to range from 10 to 15%.

The average and standard error of the mean of the values are 0.23 ± 0.02 mg Sr/g Ca. The value is similar to others found in the literature. It is always puzzling to see that the scatter agrees well with that of parameters found for most environmental biological samples (standard error ~ 40%/Vn).

Table II presents results for children from 0 to 3 years of age. Values shown in Table II are means and standard errors for each age group.

Determinations in different bones from the same child show no significant variations within the skeleton. (Consistent with information available elsewhere.) The level of stable strontium appears to increase slightly with age.

Adult bones (ribs) were collected from several places in the country. The results are shown in Table III.

Although the corresponding diets are quite different, values do not show important scatter. No information is available at present on the Sr/Ca ratio in specific diets, but the average adult bone level (0.37 ± 0.01 mg Sr/g Ca) is in excellent agreement with the Buenos Aires diet value (~ 1.7 mg Sr/g Ca), assuming a discrimination factor of 0.23.

c) Natural Strontium in Diets and Discrimination Factors

Samples analyzed are suplicates of those used for the Sr-90 survey. The milk survey is quite extensive and the values are representative of the Buenos Aires milk-shed area. The coverage of formula milk and other preparations important in

diets of children is also adequate.

Table IV shows the results for baby foods (means and standard errors).

We do not have at present good data on other individual food items; a large number of samples are under process. However, several composite diets have been analyzed. The composition of these samples were based on dietary information presented in the 1962-1963 Progress Report and results are shown in Table V.

The Sr/Ca ratio of bones can be related to those of diet with a crude model implied in the following expression:

$$(Sr/Ca)_{bone} = \frac{Ca_f \cdot R_M \cdot f_t + \sum_i Ca_i \cdot R_i \cdot f_i}{Ca_f + \sum_i Ca_i}$$

where Ca_f is the amount of fetal calcium (from placental origin),
R_M is the Sr/Ca ratio in the mother's diet,
f_t is the total discrimination-mother's diet to fetus,
Ca_i is the amount of calcium incorporated during period i,
R_i is the Sr/Ca ratio in the child's diet during period i,
f_i is the child's discrimination factor (diet-bone) during period i.

Data of Tables I, II, and V, together with information on the amounts of calcium involved, allows an estimation of the discrimination factors as shown in Table VI. Calcium increments are those estimated in the 1962-1963 Report (based on 24 grams at birth and retention fitting the expression:

$$\frac{\text{Ca retained}}{\text{Ca ingested x Weight}} = \text{Constant}$$

which is fairly good in childhood).

Results agree quite well with those of the 1962-1963 Progress Report, derived from Sr-90 data. It should be pointed out that the calculation of discrimination factors shown above is iterative and that uncertainties pile up along the way. More significance, therefore, can be attached to values of D.F. for the younger age groups.

The total discrimination(mother's diet-fetal bone) is comparable to that observed in other species and to some published values for man.

Strontium-90 in Diet

Since the last Progress Report a considerable number of new data have become available. The principal aim pursued was to observe time-trends. Sampling and analytical procedures were those described in the 1962-1963 Progress Report.

a) Milk and Baby Foods Based on Milk Products

The milk survey is representative of the Argentine Littoral Area, Table VII gives the levels grouped by 6 month periods, together with fallout data.

Milk and fallout Sr-90 are believed to be related by the expression:

$$C = a D + b d,$$

where C is the average level of Sr-90 in milk (pc/g Ca),
D is the cumulative deposition (mc/Km^2),
d is the average Sr-90 fallout rate in the period (mc/Km^2/year),
and a and b are proportionality factors.

Using the data of Table VII, these proportionality factors, computed by multiple regression, are:

$$a = 0.27 \quad \text{and} \quad b = 0.42.$$

Using the expression shown above milk levels can be computed, the standard deviation of the estimate being ± 0.37 pc/g Ca.

Table VIII summarizes the results for special baby foods based on milk. As some brands are "fortified" with mineral or animal calcium and others contain cereal products, correlations with the levels of milk cannot easily be obtained. The scatter of individual samples was similar for the various brands, with standard deviations of 15 to 40% of the average.

b) Other Food Items

Values for other food items, including commercial preparations based on cereals, are shown in Table IX.

Scatter is larger than with milk products (sampling is poorer), and the standard deviations range from 20 to about 70%. Each entry corresponds to 10-50 samples.

Data of Tables VII, VIII, and IX, together with dietary information included in the last Progress Report, show that from 1961 to 1963 Sr-90/Ca in total children' diet has increased about 40% for all age groups.

At present a detailed calculation of Sr-90 daily intakes in different age groups (in the line of Table III of the last Report) is being prepared for 1962 and 1963, attempting a classification by regional diet types.

Strontium-90 in Stillborns

During 1963, 23 samples from stillbirths were analyzed for Sr-90. The group, which contained a few samples from subjects having lived up to 7 days, is well spread in time over the year. Table X summarizes the data.

The average level and its standard error are 0.77 ± 0.04 pc/g Ca. As the average Sr-90/Ca ratio in total adult diet in 1962-1963 was 7.1 pc/g Ca, a total discrimination (mother's diet-fetal bone) of 0.11 is computed. This value is in excellent agreement with the one derived from natural strontium measurements.

TABLE I

Stable Strontium in Stillbirths

Sample code		Ca % (in ash)	Sr ppm (in ash)	mg Sr / g Ca
S/Sr-1963	4	27.5	70	0.25
	23	31.8	30	0.10
	25	34.1	40	0.12
	27	32.0	60	0.19
	30	34.6	30	0.23
	31	34.2	70	0.21
	34	35.7	70	0.20
	35	32.0	50	0.17
	39	34.4	70	0.20
	40	33.2	70	0.21
	41	32.3	50	0.16
	56	21.7	100	0.46
	57	31.7	70	0.22
	58	33.0	70	0.21
	59	24.9	120	0.48
	69	35.7	82	0.23
	70	32.7	83	0.25
			MEAN ± S.D.	0.23 ± 0.10

TABLE II

Stable Strontium in Children's Bones

Age group	Number of samples	Mean of age	Ca % (in ash)	Sr ppm (in ash)	mg Sr / g Ca
0-3 mos.	19	30 days	28.5	77	0.25 ± 0.02
3-6 mos.	16	114 days	30.0	87	0.29 ± 0.04
6-9 mos.	12	243 days	35.7	85	0.24 ± 0.02
9-12 mos.	15	349 days	31.9	71	0.31 ± 0.02
12-24 mos.	3	18 mos.	36.0	110	0.32 ± 0.05
24-36 mos.	5	34 mos.	34.7	142	0.41 ± 0.07

TABLE III

Adults Bones (Ribs)

(Age 20 and Up)

Sample Code	Age	Ca % (in ash)	Sr ppm (in ash)	mg Sr / g Ca
S/Sr-1963				
10	37	32.0	130	0.41
11	48	34.2	160	0.47
12	47	31.8	110	0.35
13	65	33.0	120	0.36
14	37	31.2	140	0.45
15	62	34.0	180	0.53
16	49	33.7	150	0.44
18	51	30.9	120	0.39
19	72	32.8	100	0.31
20	29	30.2	100	0.33
42	37	34.3	130	0.38
43	51	35.3	100	0.28
44	69	36.0	130	0.36
45	68	34.0	130	0.38
46	67	35.0	140	0.40
47	54	34.0	140	0.41
49	42	34.0	130	0.38
50	57	30.4	80	0.27
52	58	35.0	140	0.40
72	20	33.1	70	0.21
74	34	33.5	110	0.33
75	72	32.5	100	0.31
77	57	34.2	170	0.50
81	23	33.1	120	0.36
83	58	34.1	150	0.44
84	60	32.5	80	0.25
			MEAN ± S.D.	0.37 ± 0.08

TABLE IV

Mean Stable Strontium in Baby Foods

	Number of samples	Ca % (in ash)	Sr ppm (in ash)	mg Sr / g Ca
Milk	24	15.0	140	0.95 ± 0.08
Baberlac comp.	10	11.8	123	0.85 ± 0.09
Milk Nido	10	11.3	140	1.26 ± 0.21
Eledón con fécula y glúcidos	10	15.6	116	0.92 ± 0.06
Baberlac simple	10	11.3	171	1.50 ± 0.20
Biberol	9	14.2	70	0.48 ± 0.08
Yogalmina	10	15.2	90	0.59 ± 0.09
Levulosa	10	17.4	200	1.15 ± 0.05
Osteolact	10	15.3	110	0.72 ± 0.06
Secalbum	10	25.2	551	2.28 ± 0.38
Nestógeno	10	13.7	140	1.02 ± 0.15
Nestún	10	6.4	170	2.65 ± 0.40
Eledón con fécula	10	14.6	100	0.69 ± 0.05
Quaker	7	3.13	310	9.91 ± 1.10
Farex	10	25.0	200	0.80 ± 0.06

TABLE V

Stable Strontium in Total Diet(1)

Age Group	mg Sr/g Ca	Calcium intake (g/day)	Strontium intake (mg/day)
0-3 mos.	0.69(2)	1.00	0.69
3-6 mos.	0.97(3)	0.99	0.96
6-9 mos.	1.21	0.84	1.02
9-12 mos.	1.24	0.86	1.07
12-24 mos.	1.31	0.72	0.94
24-36 mos.	1.35	0.68	0.92
Adults	1.75	0.70	1.22

(1) Diet composition based on Table III of 1962-1963 Progress Report.
(2) The value is computed from measured diet and 47% of breast feeding calcium contribution, assuming an OR (diet mother-milk) of 0.12.
(3) The value includes breast feeding (17% of calcium intake) in the way shown above.

TABLE VI

Discrimination Factors

Age Group	D. F.
stillbirth	0.13*
0-3 months	0.81
3-6 months	0.49
6-9 months	0.50
9-12 months	0.28
12-24 months	0.30
24-36 months	0.22

* This is the total discrimination mother's diet-fetal bone.

TABLE VII

Fallout and Sr-90 in Milk

Period	Cummulative deposition (mc/Km^2)	Average Fallout Rate (mc/Km^2 year)	Average level in milk (pc/g Ca)
1st semester 1960	6.8	0.60	1.63
2nd semester 1960	7.1	1.02	2.14
1st semester 1961	7.7	0.96	1.85
2nd semester 1961	8.0	1.40	3.22
1st semester 1962	8.8	0.70	3.05
2nd semester 1962	9.4	2.68	3.54
1st semester 1963	10.6	1.15	3.31
2nd semester 1963	11.5	2.21	4.17

TABLE VIII

Baby Foods (pc Sr^{90}/g Ca)

Brand	1961	1962	1963
Baberlac compuesto	1.05	1.47	2.32
Eledón con fécula	0.85	2.65	2.37
Eledón con fécula y glúcido	4.02	2.37	2.41
Baberlac simple	3.52	3.48	3.72
Nestógeno	3.19	3.68	3.00
Casenolín	1.85	0.49	1.51
Secalbum	0.82	0.51	0.26
Yogalmina	2.96	2.98	2.23
Leche Nido	2.17	1.88	2.37
Leche Kasdorf	5.03	4.61	5.20
Leche S.M.A.	3.14	3.13	2.82
Leche Cundor	2.60	2.60	2.83
Osteolack	3.03	3.79	3.32

TABLE IX

Other Foods (pc Sr^{90}/g Ca)

	1961	1962	1963
Flour	15.58	19.91	18.20
Semolina	17.93	22.41	20.11
Farex	0.80*	0.95	0.64
Maizena	3.85	2.75	--
Quaker	8.18	8.18	10.26
Potato	14.85	18.47	18.24
Calabash	3.15	8.44	5.31
Onion	12.80	16.07	14.63
Tomato	23.95	28.94	25.95
Pool of vegetables**	6.45	8.06	8.60
Banana	5.90	6.42	6.04
Apple	6.26	7.77	7.40
Eggs	5.24	6.55	7.01

* The 1962-1963 Progress Report has an incorrect value for the 1961 level.
** Pooled according to consumption (1962-1963 Progress Report).

TABLE X

Strontium-90 in Stillborn

Sample Code	pc/g Ca	% Ca in ash	Month of death
213	0.58	45.7	2
215	0.62	27.5	5
216	0.62	34.1	5
233	0.55	34.5	6
240	0.59	35.0	6
241	0.50	34.0	8
244	0.46	31.8	6
246	0.61	34.0	8
248	0.57	34.0	8
249	0.88	29.4	8
254	0.71	34.6	8
254A	0.62	34.0	8
255	0.86	34.2	8
218	0.33	32.8	6
245	0.55	33.8	8
258	0.74	35.7	8
266A	1.04	34.4	9
266	1.19	36.0	9
267	1.15	33.2	9
268	0.83	32.2	10
268A	1.12	32.3	10
275	1.30	21.7	10
276	1.21	31.7	11