06.64.10

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Strontium-90 Levels in the Diets and Bones of Children

PROGRESS REPORT - 1962-1963

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Introduction

Since children have a high rate of bone formation their skeleton tends to follow readily the changes in levels of Sr-90 in the diet, this being especially true during the first year of life. Knowledge of correlating parameters between diet and bone in that period is therefore particularly important to estimate children's body burdens resulting from different environmental conditions.

These estimates are complicated by the fact that the diet of very young children is composed essentially of specially processed food items based on milk with several additions, and these materials cannot be easily correlated with adult alimentation which is normally surveyed in fallout programs. An additional incentive to study the Sr-90 content of diet and bones of children in Argentina was the need for systematic data in a region for which there is only scanty information on the subject.

The study was "a priori" facilitated by the fact that Sr-90 fallout in the Argentine Litoral Area has remained relatively constant during the last years(1)(2)(3) (1959 - 1.2 mc/Km^2; 1960 - 0.9 mc/Km^2; 1961 - 1.2 mc/Km^2; 1962 - 1.3 mc/Km^2); this being reflected also in the small variation of Sr-90 levels in several food items. The study could therefore be carried out over several years, simplifying the attempt to estimate discrimination factors.

The work carried out had two purposes: a) the estimation of representative average levels of Sr-90 in children's alimentation, and b) the determination of Sr-90 in bones from children whose "diet history" could be established with some reliability.

Sampling and Analytical Procedures

Specially produced baby food (formula and evaporated milks, etc.) were sampled at the comsumption point, at a rate of about 4 to 6 samples per month per brand. The samples of each brand were pooled approximately every month and processed. This time scheme was altered when convenient in relation with information from the producing companies.

Other food items were already being sampled by the regular CNEA survey, but the emphasis was shifted in connection with the reported work. The sampling was also carried out at the consumption point since no time trends of fallout food levels correlation studies were planned. The samples were obtained at random once a week and pooled and processed every month.

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Bone samples were obtained when available mainly from four Hospitals (Hospital de Niños de Buenos Aires, Casa Cuna, Hospital Rawson and Hospital Pirovano). Information was obtained from these hospitals on the alimentation in each case. In addition the family and the intervening medical practitioner were interviewed on the subject. Since sometimes the information was not available the number of bones with a corresponding "diet history" is smaller than the total number of bones processed.

All samples were processed using HASL radiochemical procedures[4]. Sr-90 was measured by counting its daughter Y-90 in low background β-counters (backgrounds ranging from 0.3 to 0.9 cpm). The chemical yields were determined by Sr-85 tracer and γ-counting; Ca contents were determined by gravimetric techniques.

Strontium-90 in Diets of Children

The survey covered different brands of baby foods in addition to diet items which are common to adult alimentation.

Table I presents averages and standard error of the mean for Sr-90 levels in baby foods based on milk products. The values are considered to be representative of the material available in the market in the period 1960 to 1962.

The scatter of values of individual samples was similar for the different brands, with standard deviations ranging from 20 to 40% of the average.

As some of the brands are "fortified" with mineral or animal calcium, and others include cereal products, no correlation can readily be obtained with the levels observed in cow milk of the Argentine Litoral Area. However, baby foods having higher calcium proportions in ash tend, as expected, to have lower Sr-90/Ca levels.

Values for other food items are shown in Table II. The table includes also prepared foods based on cereals. The scatter of values was higher than those of Table I, with standard deviations ranging from 30 to 70%. Potato levels are particularly variable and not too much significance should be attributed to the mean.

The estimation of Sr-90/Ca levels in the diet of children of different age groups requires information as to the proportions of Ca contributed by the food components. This information is not available for several regions in Argentina and could be obtained with a reasonable degree of reliability only for Buenos Aires Province[5][6]. Regional differences are probably of little importance in the case of infants as most of the dietary calcium is provided by specially prepared milk products (evaporated, formula, etc.) which are mostly of national distribution.

Table III shows the Sr-90 estimates for several age groups in Buenos Aires Province. Some uncertainity is introduced by the contribution of breast feeding, which is of particular importance in the 0-3 month group. The levels in this case were computed from those of the adult diet using an OR of 0.12. Meat was not included in the Table in view of its negligible contribution to the Ca intake even in the older age group.[9]

The data shows that during the first year of life milk and specially prepared formula and evaporated milks contribute about 80% of the calcium and 85% of the Sr-90 intake. A similar contribution was estimated elsewhere[7]. Table III shows that the average level of total diet during the first year of life was about 2.5 pc/g Ca, which is also the mean level measured in milk during the period of study.[2][3]

Sr-90 in Bones of Children

Experimental evidence suggests that the skeleton turn-over is very high in the first two years of life[8]; this means that no differences of Sr-90 levels should be expected among bones in very young children. This is important since the results reported corresponded generally to at most a few bones per child and the attempted correlations with diet depends on the assumption of uniform labeling.

Table IV presents bone level averages and standard errors of the mean for four age groups.

A large part (65%) of the samples were obtained from children only recently admitted to the supplying hospitals and coming from several regions of the country; it was therefore impossible to collect reliable information on their "integrated" diet. For the remaining 35% enough information could be collected, so as to estimate their average diet during different periods of their life (averaged over periods of 6 months).

Tables 5a, 5b, 5c and 5d present the information on these bones and the estimates of the past diets. The relevance of the estimates is different for the various age groups. While reliable information can be collected from mothers and doctors concerning alimentation during the first six months, the same does not apply to other age groups. Furthermore in the studied area most new born alimentation remain under medical supervision for only a few months.

The averages and scatter of Sr-90 levels for the groups presented in Tables 5a to 5d do not differ significantly from those obtained including all samples and therefore the group does not seem to be biased.

From these data an estimation of discrimination factors has been attempted. The Sr-90/Ca level in bone is related to that of the diets by the following general expression:

$$(\text{Sr-90/Ca})_{\text{Bone}} = \frac{Ca_f \cdot L_M \cdot F_M + \sum \Delta Ca_i \, L_i \, F_i}{Ca_f + \sum i \, \Delta Ca_i}$$

where Ca_f is the amount of calcium from placental origin,
L_M is the Sr-90/Ca ratio in the mothers total diet,
F_M is the OR blood/diet in the mother (0.25),
F_p is the placental discrimination factor (0.5),
$\Delta^P Ca_i$ is the amount of Ca incorporated into the bone in the period i,
L_i is Sr-90/Ca ratio in the diet of the child in the period i, and
F_i is the average OR bone/diet of the child during the period i.

From the data of Tables 5a to 5d the child discrimination factor (F_i) during the period of six months could "a priori" be calculated. However, it is clear that any of these estimations require the knowledge of all F up to F_{i-1}; the computations are therefore iterative and the uncertainty increases in every step. For this reason and since the "integrated" diet is known with some reliability for the 0-6 months group, the computation child by child has been restricted to this age period (Table 5a).

Other information is also needed for the calculation. The Ca content of new born children in the Argentine Litoral Area is estimated to be about 24 g[10]. Several calculations performed on published data[11][12] pointed to the fact that the increase of calcium in the child fits reasonably well the expression:

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

From this relation calcium increment at different ages can be estimated and this was used in connection with Table 5a. Again a new and not readily assessed uncertainty is introduced here.

The approach presented leads to a value of 0.81 ± 0.27 for the OR bone/diet of the 0-6 months children group. This value gives the impression of being quite different from the adult discrimination factor, but all the uncertainties introduced here (and also present in the adult value of 0.25) would not allow any clearer conclusion.

Another approach has also been used with the data of Tables 5a to 5d. Since the skeleton Ca increased during each of the 6 months periods does not differ appreciably from linearity, the calculations could be carried out with an "average" child of each group. This has been done in Table 6.

The uncertainties involved in these calculations are substantially large and cannot be even estimated. The results should therefore be considered merely as a construction. It is suggestive, however, that the trend of change of the computed discrimination factors is similar to that estimated in other areas[8]. Although the actual values differ for the second year. It is also interesting that the value found for the older groups is the same as the accepted OR for adults.

It is clear that more data are needed to resolve differences of discrimination factors with age, the number required being larger as older age groups are considered. It seems also of interest to attempt a fractionation of the groups, again with more data, since the evidence suggests that discrimination changes considerably during the first year of life.

The same type of approach with stable strontium data would help considerably in the interpretation and would make the results clearly independent of changes in the contamination levels, which increase the difficulties of estimation.

Several methods of stable Sr measurement have been tried in our laboratory with erratic results. A simple method was finally developed and diets and bones are being measured. However, the amount of data obtained is so far insufficient for attempting the correlation.

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TABLE I

Baby Foods

Brands	Ca (%/g ash)	Sr^{90}+ pc/g Ca
"Baberlac Compuesto"	28.30	1.05 ± 0.10
"Eledón con fécula"	16.17	1.75 ± 0.14
"Eledón con fécula y glúcido"	13.76	3.36 ± 0.25
"Baberlac simple"	11.56	3.52 ± 0.40
"Nestógeno"	9.96	3.06 ± 0.25
"Casenolín"	13.99	1.85 ± 0.16
"Secalbum"	27.52	0.82 ± 0.07
"Yogalmina"	14.90	2.96 ± 0.24
"Leche Nido"	10.84	2.17 ± 0.10
"Leche Kasdorf"	2.15	5.03 ± 0.38
"Leche S.M.A."	11.67	2.82 ± 0.22
"Leche Cyndor"	13.40	2.60 ± 0.21
"Osteolact"	10.00	3.03 ± 0.32

+ Values are means and standard errors of the mean.

TABLE II

Other Food Items

Food Items	Ca (mg/100 g food)	Sr^{90}+ (pc/g Ca)
Wheat flour	24.2	15.58 ± 1.74
Semolina	21.0	17.93 ± 0.16
"Farex" (flour with addition of animal bone calcium)	622.9	5.33 ± 0.48
"Maizena"	7.8	3.85 ± 1.05
"Quaker"	23.7	8.18 ± 0.73
Potatoe	6	14.85 ± 6.72
Calabash	20.8	5.15 ± 0.16
Onion	5.5	12.80 ± 0.05
Composite of Vegetables++ Onion, Tomato, Parsley, Leak, Carrot, Lettuce	19.8	6.45 ± 0.26
Banana	27.2	5.90 ± 0.76
Apple	2.7	6.36 ± 0.14

\+ Values are means and standard errors of the mean.
++ Composited according to information on consumption by children[6].

TABLE III

Diet of Children

Age 0-3 months	Ca g/day	Sr-90 level	Sr-90 pc/day
Breast feeding	0.470	0.63	0.30
Milk	0.280	2.50	0.70
Formula and other special foods	0.250	2.68	0.67
TOTAL	1.000		1.67
			1.67 pc Sr-90/g Ca
Age 3-6 months			
Breast feeding	0.165	0.63	0.10
Milk	0.370	2.50	0.92
Formula and other special foods	0.003	14.85	0.04
TOTAL	0.538		1.06
			2.35 pc Sr-90/g Ca
Age 6-9 months			
Milk	0.400	2.5	1.00
Milk plus cereals	0.400	2.79	1.12
Potato	0.006	14.85	0.09
Calabash	0.003	5.15	0.02
Banana	0.004	5.90	0.02
Apple	0.002	6.36	0.01
Cereals	0.004	15.58	0.06
Eggs	0.020	5.25	0.10
TOTAL	0.839		2.42
			2.88 pc Sr-90/g Ca

TABLE III - cont'd.

Diet of Children

Age 9-12 months	Ca g/day	Sr-90 level	Sr-90 pc/day
Milk	0.400	2.5	1.00
Formula and other special foods	0.400	2.79	1.12
Potato	0.006	14.85	0.09
Calabash	0.002	5.15	0.01
Banana	0.006	5.90	0.04
Apple	0.004	6.36	0.03
Cereals	0.006	15.58	0.93
Eggs	0.040	5.24	0.21
TOTAL	0.864		3.43
			3.97 pc Sr-90/g Ca

Age 12-24 months	Ca g/day	Sr-90 level	Sr-90 pc/day
Milk	0.650	2.5	1.63
Potato	0.009	12.85	0.13
Calabash	0.002	5.15	0.01
Banana	0.006	5.90	0.04
Apple	0.004	6.36	0.03
Cereals	0.010	15.58	0.16
Egg	0.040	5.24	0.21
TOTAL	0.721		2.21
			3.07 pe Sr-90/g Ca

TABLE III - cont'd.

Diet of Children

Age 24-36 months	Ca g/day	Sr-90 level	Sr-90 pc/day
Milk	0.600	2.5	1.50
Potato	0.012	14.85	0.18
Calabash	0.002	5.15	0.01
Banana	0.006	5.90	0.04
Apple	0.004	6.36	0.05
Cereals	0.014	15.58	0.22
Egg	0.040	5.24	0.21
TOTAL	0.678		2.21

3.26 pc Sr-90/g Ca

TABLE IV

Sr-90 in Bone

Age Group	No. of samples	% Ca in ash	Sr^{90} pc/g Ca
0-6 months	43	33.9	0.81 ± 0.04
6-12 months	27	35.2	0.68 ± 0.03
1-2 years	38	34.9	0.70 ± 0.04
2-3 years	48	36.1	1.20 ± 0.09

TABLE 5a

Bone Samples with Diet Information

Age	Date of birth	Bone pc/g Ca	Diet 0-6 months pc/g Ca
15 days	8-1961	0.72 ± 0.08	1.53
22 days	8-1961	0.53 ± 0.05	1.00
25 days	7-1961	0.60 ± 0.06	1.04
33 days	6-1961	0.84 ± 0.08	0.97
45 days	7-1961	0.57 ± 0.09	0.63
48 days	9-1961	0.67 ± 0.10	1.71
60 days	4-1961	0.96 ± 0.12	2.00
62 days	8-1961	0.69 ± 0.08	0.93
90 days	3-1961	0.72 ± 0.11	1.53
90 days	6-1961	0.64 ± 0.11	1.83
90 days	12-1961	1.00 ± 0.07	2.14
140 days	7-1961	1.07 ± 0.20	0.75
180 days	6-1961	0.98 ± 0.10	2.22
180 days	6-1961	0.97 ± 0.12	2.56

Average diet of mother 5.1 pc/g Ca. Ca at birth 24 grams.

TABLE 5b

Bone Samples with Diet Information

(6-12 months)

Age	Date of birth	Bone pc/g Ca	Diet 0-6 months pc/g Ca	Diet 6-12 months pc/g Ca
6.3 mos.	2-1962	0.51 ± 0.09	0.97	1.82
8.0 mos.	3-1961	0.93 ± 0.06	1.18	2.76
8.0 mos.	7-1961	1.10 ± 0.08	1.18	2.76
8.0 mos.	3-1961	0.55 ± 0.10	1.23	2.50
8.8 mos.	6-1961	0.58 ± 0.06	1.14	2.66
10.0 mos..	1-1961	0.54 ± 0.08	0.64	2.35
10.0 mos.	4-1961	0.69 ± 0.09	1.22	2.90
10.5 mos.	10-1960	0.96 ± 0.10	1.32	2.34
12.0 mos.	9-1960	0.60 ± 0.07	1.57	2.42
12.0 mos.	7-1960	0.52 ± 0.07	1.01	2.61

TABLE 5c

Bone Samples with Diet Information
(12-24 months)

Age	Date of birth	Bone pc/g Ca	Diet 0-6 months pc/g Ca	Diet 6-12 months pc/g Ca	Diet 12-24 months pc/g Ca
14.0 mos.	8-1960	0.32 ± 0.09	0.51	1.00	2.18
14.0 mos.	11-1960	0.51 ± 0.10	1.20	2.13	3.62
15.0 mos.	8-1960	0.87 ± 0.10	1.20	2.13	3.62
15.0 mos.	12-1960	0.78 ± 0.07	1.20	2.13	3.62
16.0 mos.	2-1960	0.41 ± 0.09	1.20	2.13	3.68
20.0 mos.	1-1960	1.28 ± 0.07	1.20	2.13	4.23
17.5 mos.	12-1960	0.61 ± 0.04	1.20	2.13	3.62
22.5 mos.	4-1960	0.51 ± 0.06	1.20	2.13	4.08
24.0 mos.	7-1959	0.65 ± 0.06	1.20	2.13	3.66
24.0 mos.	8-1959	0.75 ± 0.04	1.20	2.13	3.88
24.0 mos.	9-1959	0.69 ± 0.09	1.20	2.13	3.29
24.0 mos.	7-1960	0.80 ± 0.13	1.60	2.05	3.53
24.0 mos.	7-1960	1.07 ± 0.07	0.90	1.47	3.68

TABLE 5d

Bone Samples with Diet Information
(24-36 months)

Age	Date of birth	Bone pc/g Ca	Diet 0-6 months pc/g Ca	Diet 6-12 months pc/g Ca	Diet 12-24 months pc/g Ca	Diet 24-36 months pc/g Ca
28.0 mos.	2-1959	0.53 ± 0.11	1.15	1.99	3.59	3.68
30.0 mos.	3-1959	1.10 ± 0.09	1.15	1.99	3.59	3.68
30.0 mos.	2-1960	0.91 ± 0.06	1.15	1.99	3.59	3.68
30.0 mos.	3-1960	0.61 ± 0.24	1.15	1.99	3.59	3.68
36.0 mos.	8-1958	0.83 ± 0.10	1.15	1.99	3.59	3.68
36.0 mos.	11-1958	0.55 ± 0.08	1.15	1.99	3.59	3.68

TABLE 6

Discrimination Factors for Age Groups

Group	Average Age (months)	Average Bone Sr^{90}/Ca, pc/g	L (0-6 mos.) pc/g Ca	L (6-12 mos.) pc/g Ca	L (12-24 mos.) pc/g Ca	L (24-36 mos.) pc/g Ca	L_M pc/g Ca	F
0-6	2.5	0.79	1.45	--	--	--	5.1	0.75
6-12	9.4	0.70	1.15	2.51	--	--	3.3	0.35
12-24	19.5	0.71	1.15	1.99	3.59	--	3.3	0.25
24-36	32.0	0.76	1.15	1.99	3.59	3.68	3.3	0.25

$\bar{\Delta}$ Ca 0-2.5 months - 12.5 grams

$\bar{\Delta}$ Ca 0-6 months - 30.4 grams; $\bar{\Delta}$ Ca 6-9.4 months - 17.3 grams

$\bar{\Delta}$ Ca 6-12 months - 30.4 grams; $\bar{\Delta}$ Ca 12-19.5 months - 25.0 grams

$\bar{\Delta}$ Ca 12-24 months - 39.6 grams; $\bar{\Delta}$ Ca 24-32 month - 17.9 grams