VARIATIONS IN THE CALCIUM METABOLISM OF PRE-SCHOOL CHILDREN ON A MEDIUM PROTEIN DIET

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THESIS

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Introduction

There has been considerable attention paid to the calcium requirements of pre-school children in recent years. While children of this age had previously acted as subjects in some dietary studies, until recently they had served in few balance studies. Calcium is an important constituent of the bones, teeth and blood and it is especially needed by children of pre-school age because of the rapid growth and bone development.

This paper is only a portion of an investigation of the metabolism of healthy pre-school children. The reasons for conducting this part of the investigation were; first, to study the daily variations in the calcium retentions of four normal pre-school children on a fixed, medium protein diet; second, to determine the similarity of the reaction of the four children; third, to determine the actual amount of calcium stored; and fourth, to determine the relationship between the results of this study and those of other investigators.

Review of the Literature

Investigators in Germany conducted some of the first balance studies, however, the results are hardly comparable to those obtained in this country. The studies as a whole were poorly controlled, the children were undernourished and the diets were meagre.

Sherman and Hawley (14) reported one of the first balance studies with normal children as subjects. Their study included a series of four experiments. In the first series twelve children from three to thirteen years of age served as subjects. The purpose of this portion of the study was to determine the relation of calcium storage to age. The children received a normal mixed diet, including 750 grams of milk a day, for a one day preliminary and a nine day test period. The daily retentions varied from 0.15 to 0.62 gram increasing with the size and age of the children, while the retentions per kilogram were fairly uniform averaging 0.01 gram of calcium per day. Table I shows the values for the children of pre-school age.

The object of the second series was to determine the amount of milk necessary for optimum storage. In this series three children, four, five, and twelve years of age, served as subjects for eight consecutive experimental periods of six days each. The authors varied the diet each period by

systematic changes in the amount of milk used. The amounts were, 250, 500, 750, 1000, 1500, 1000, 750, and 500 grams respectively. The calcium retentions ranged from 0.008 to 0.014 gram per kilogram of body weight. Although the difference between the amount of calcium stored on 500, 750, and 1000 grams of milk was small, the authors stated that the results seemed to indicate that 1,000 grams of milk per day gave the optimum storage.

Sherman and Hawley conducted the third and fourth series to determine if the calcium from vegetables could be as well utilized as that from milk. The three children used in series II served as subjects for the third study of three, nine day periods. For the first and third period, they received a mixed with 500 grams of milk and in the second period, they received 500 grams of milk and enough additional vegetables to double the calcium content of the diet. Thus they received the same amount of calcium as in 1,000 grams of milk. The results seemed to indicate that the calcium of vegetables was not as well utilized as that of milk. The authors did not take into consideration, however, that the vegetables increased the bulk of the diet which would have a tendency to hasten the food through the body and, thus, may have lowered the calcium absorption. The children in the fourth series were not of pre-school age.

In 1927, Willard and Blunt (17) compared the influence of evaporated and commercially pasteurized milk on the calcium metabolism of four children three, four, eight, and twelve years of age. The children received 810 grams of pasteurized milk for one period and evaporated milk containing an equivalent amount of calcium for the second. A three day preliminary period preceded the experimental periods of three days each. The calcium intake for the children of pre-school age ranged from 0.064 to 0.070 gram and the retentions from 0.009 to 0.013 gram per kilogram of body weight. Table I shows that the calcium storage was higher during the period when the children received evaporated milk. The authors stated that one of the children was underweight at the time of the study and that the children's diets may have been low in calcium previous to the experimental period, therefore, the results can not be justly compared with studies having more normal conditions.

Wang and her associates (15) conducted a calcium metabolism study on ten normal and fifty undernourished children from four to thirteen years of age. During a three day preliminary and a three day experimental period, the children received a weighed diet containing from 0.061 to 0.082 gram per kilogram of body weight. The retentions varied from 0.006 to 0.019 gram per kilogram per day. Table I shows that the individual absorption and retention figures

varied widely. Nevertheless, the average retentions were higher than those observed by Sherman and Hawley.

In connection with her previous study, Wang and her associates (16) tabulated the data on eighteen children according to the intake per kilogram in order to determine the minimum calcium requirement. The daily calcium intake varied from 0.019 to 0.082 gram of calcium per kilogram of body weight and the retentions varied from 0.001 to 0.018 gram. Since a negative balance resulted when the diet contained 0.023 gram of calcium or less per kilogram of body weight, the authors concluded that for a twenty kilogram child the minimum calcium requirement was 0.46 gram per day.

To determine the influence of cereals on the calcium retention, Burton (3) conducted a study on four normal boys from three to five years of age. The study consisted of a three day preliminary period and two test periods five to six days each. The children received a fixed diet to which was added either refined wheat or oatmeal. Table I shows that the average intake on the wheat diet was 0.084 gram per kilogram and the retention was 0.048 gram while on the oatmeal diet, the intake was slightly lower, 0.080 gram per kilogram, and the retention was only 0.039 gram. The children received ultra violet light treatments during the study which may have been responsible for the higher retentions reported.

Hawks and her associates (7) determined the metabolism of three normal children of pre-school age. They had a three day preliminary and a three day collection period for each protein level of two, three, and four grams. On the 2 gram level the average calcium intake was 0.042 gram per kilogram and the retention 0.009 gram; on the 3 gram level, the intake was 0.061 and the retention 0.008 gram; and, on the 4 gram level, the intake was 0.057 and the retention was 0.015 gram per kilogram.

In an unpublished thesis, Miller (8) reported a portion of a study on two normal pre-school children. During six days following a 27 day period on the same diet, the children received 0.068 gram of calcium per kilogram and during the next nine days they received 0.077 gram. The children retained 0.005 and 0.003 gram on the former diet and both stored 0.064 gram on the latter diet.

In a preliminary paper Lunscher and others (9) reported the data on the calcium storage of four children for eleven to twenty consecutive five day periods. The children who were from three to ten years of age received 1.0 gram of calcium per day except during four to eight consecutive periods when they received 1.9 grams. When the intake was 1.0 gram, the children retained from 0.20 to 0.46 gram and when it was 1.9 gram, they stored from 0.45 to 0.67 gram of calcium per day. This report shows a wide variation in retention in relation to the calcium intake.

TABLE I

SUMMARY OF CALCIUM BALANCES PER KILOGRAM PER DAY REPORTED BY OTHER INVESTIGATORS

INVESTIGATOR	CHILDREN AGE	CHILDREN NO.	INTAKE	TOTAL OUTPUT	RETENTION TOTAL	RETENTION PER CENT	REMARKS
	YR.		GM.	GM.	GM.	%	
SHERMAN-HAWLEY	3-5	3	0.053	0.042	0.010	19.3	MIXED DIET 750 GM. MILK
(1922)	4-5	2	0.020	0.013	0.008	36.3	FIXED DIET 250 GM. MILK
	4-5	2	0.035	0.023	0.013	35.5	FIXED DIET 500 GM. MILK
SERIES TT	4-5	2	0.048	0.036	0.013	25.8	FIXED DIET 750 GM. MILK
	4-5	2	0.063	0.049	0.014	23.2	FIXED DIET 1000 GM. MILK
	4-5	2	0.089	0.076	0.009	15.7	FIXED DIET 1500 GM. MILK
SERIES TTT	4-5	2	0.033	0.026	0.007	21.0	FIXED DIET 500 GM. MILK
	4-5	2	0.051	0.046	0.004	8.7	FIXED DIET 500 GM. MILK & VEG.
WILLARD-BLUNT	3-4	2	0.070	0.058	0.013	18.5	FIXED DIET, EVAPORATED MILK
(1927)	3-4	2	0.064	0.055	0.009	13.0	FIXED DIET, PASTEURIZED MILK
WANG	5	1	0.061	0.049	0.012	19.0	10-15% UNDERWEIGHT CHILD
(1928)	4-5	2	0.061	0.042	0.019	31.0	5-10% UNDERWEIGHT CHILD
	5	1	0.082	0.075	0.006	7.4	VIGOROUS NORMAL CHILD
	5	2	0.067	0.057	0.010	14.8	NORMAL IN WEIGHT ONLY CHILD
WANG	5	1	0.019	0.020	0.001	6.3	NORMAL CHILD
(1930)	5	1	0.082	0.072	0.009	11.3	NORMAL CHILD
	4	1	0.041	0.024	0.017	42.2	NORMAL CHILD
	4	1	0.049	0.031	0.018	37.3	NORMAL CHILD
BURTON	3-5	4	0.084	0.041	0.048	55.0	WHEAT CEREAL, ULTRA VIOLET LIGHT
(1930)	3-5	4	0.080	0.045	0.039	46.0	OATMEAL, ULTRA VIOLET LIGHT
HAWKS	4-5	3	0.042	0.033	0.009	21.4	2 GM. PROTEIN
	4-5	3	0.061	0.054	0.008	12.9	3 GM. PROTEIN
	4-5	3	0.057	0.042	0.015	26.3	4 GM. PROTEIN
HALLER	4½	1	0.065	0.060	0.005	7.7	MEDIUM PROTEIN DIET
(1932)	4½	1	0.065	0.062	0.003	5.0	MEDIUM PROTEIN DIET
	4½	1	0.077	0.075	0.002	2.6	HIGH PROTEIN DIET
	4½	1	0.077	0.075	0.002	2.6	HIGH PROTEIN DIET
PORTER-LEVEN	5	1	0.039	0.035	0.004	10.0	PLAIN CEREAL
I (1933)	5	1	0.039	0.037	0.002	5.0	PLAIN CEREAL
	3	1	0.042	0.039	0.003	7.0	PLAIN CEREAL
	3	1	0.041	0.036	0.005	12.0	PLAIN CEREAL
	5	1	0.046	0.028	0.018	39.0	IRRADIATED CEREAL
	5	1	0.037	0.028	0.009	24.0	IRRADIATED CEREAL
	3	1	0.045	0.031	0.014	31.0	IRRADIATED CEREAL
	3	1	0.042	0.033	0.009	21.0	IRRADIATED CEREAL
PORTER-LEVEN	5½	1	0.043	0.038	0.005	10.9	CONSECUTIVE DIET
II (1933)	2½	1	0.064	0.055	0.009	14.9	CONSECUTIVE DIET
	4-2/3	1	0.054	0.047	0.007	13.5	CONSECUTIVE DIET
DANIELS &	4½	11	0.051		0.010	19.6	COD LIVER OIL
CO-WORKERS	4½	10	0.082		0.010	12.2	COD LIVER OIL
(1933)	4½	10	0.051		0.008	15.7	COD LIVER OIL - VIOSTERAL
	5	8	0.081		0.008	9.8	COD LIVER OIL-VIOSTERAL
	4½	3	0.049		0.007	14.3	SUNSHINE
	5	4	0.077		0.008	10.4	SUNSHINE
DANIELS &	4½	1	0.072		0.014	19.4	
CO-WORKERS	5	1	0.069		0.014	20.3	
(1935)	5	1	0.047		00014	28.1	
	3	1	0.092		0.013	14.1	
	4½	1	0.054		0.012	22.2	
	4½	1	0.073		0.012	16.3	
	5	1	0.075		0.012	16.0	
	4	1	0.051		0.011	21.6	
	4½	1	0.046		0.011	23.9	
	6	1	0.081		0.012	14.8	
	4	1	0.086		0.010	11.6	
	4½	1	0.043		0.011	25.6	
	6	1	0.087		0.010	11.5	
	6	1	0.080		0.009	11.3	
	3	1	0.054		0.009	16.7	
	5	1	0.054		0.008	14.8	
	5½	1	0.044		0.007	15.9	
	5½	1	0.044		0.007	15.9	
	5	1	0.044		0.007	15.9	
	4	1	0.057		0.007	12.3	

Porter-Levin (11) conducted a study to determine the metabolism of two normal pre-school children. She divided the investigation into two parts in which the children received either non-irradiated or irradiated cereals. Each set consisted of four periods, a preliminary period, a five day test period, an intermediate period, and another five day test period. During the preliminary and intermediate periods, which were from fourteen to twenty three days long, the children received a basal diet which was taken ad libitum except for butter, milk, and cereal which were kept constant. During the test periods the diet was constant and the children received from 0.077 to 0.046 gram of calcium per kilogram per day. Although there was a wide variation in retention on both of these diets, the general trend seemed to indicate that irradiated cereals increased calcium storage, since they retained from 0.009 to 0.018 gram when they received irradiated cereals and only from 0.002 to 0.005 gram when they received plain cereals. (Table I).

Since there were considerable variations in the retentions in her previous study, Porter-Levin (12) conducted a second investigation to determine the daily fluctuations in retention over a consecutive period of time. Three normal children, from two and one-half to five and one-half years of age, served as subjects for this study of twenty successive three day periods. A preliminary period

of one to three days was considered sufficient. A three day meal schedule was repeated each period throughout the twenty periods. The diet contained one gram of calcium per day for each of the children or from 0.043 to 0.064 gram per kilogram of body weight. A wide individual variation from period to period was noted with retentions ranging from 0.11 to 0.14 gram of calcium per day or from 0.005 to 0.009 gram per kilogram of body weight. The author concluded that in order to cover the entire range of variation in retentions, it required from 15 to 21 consecutive days on a constant diet.

To determine the calcium requirements of eight children from three to five years of age, Daniels and her co-workers (4) reported a balance study comprising forty-six metabolism periods. They divided this investigation into three series. In series I, the children received cod liver oil, in series II, they received cod liver oil and viosterol and in series III, they received neither cod liver oil nor viosterol, since this portion of the study was conducted in the summer. For part of each series the children received a pint of milk a day and for the rest of the study they received a quart of milk. Since they stored approximately the same amount of calcium whether they received a pint or a quart of milk a day, the authors concluded if the diet contained adequate amounts of phosphorus, protein, fat, and vitamins, a pint of milk a day would furnish enough

calcium to meet the requirements of normal pre-school children (Table I). They also stated that the amount of calcium retained was not primarily related to the amount of Vitamin D in the diet if the diet contained more than a pint of milk a day.

Two years later these same investigators (5) reported a second study to determine the calcium needs of pre-school children. Twenty children, three to six years old, received a mixed diet containing a sufficient amount of Vitamin D, for a preliminary period of seven days and for two consecutive test periods of four to five days each. The authors varied the proportion of the calcium intake obtained from milk, from 73 to 91 per cent. Table I shows that the ingested calcium per kilogram varied from 0.042 to 0.092 gram. The retentions ranged from 0.007 to 0.014 gram, 74 per cent of which were 0.010 gram per kilogram of body weight or less. The authors believed that these results seemed to show that the amount of calcium required by normal pre-school children may be lower than has hitherto been considered necessary. They suggested that the retentions may be related to the physiological condition of the children as well as to their size.

In all studies of this nature, there are many unavoidable errors. Early investigators did not recognize these errors but with further investigation they became apparent. One of these errors was the short length of the

preliminary period. It was assumed that children became adjusted to a diet in from one to three days, but a longer period now seems advisable. The length of the test period in the first studies was also short. Since later studies have shown that there is considerable variation from period to period, the short test period may have produced inaccurate balances because the period may have been one in which the retention was either high or low. An average of several test periods seems advisable to show the metabolic tendencies. There are other errors such as the collection of feces samples. This source of error is still an important factor.

The first investigators knew nothing concerning the relationship between Vitamin D and calcium storage. Burton (3) reported very high retentions probably due to the ultra violet light treatments which the children received. Porter-Levin (11) found that irradiated cereals seemed to increase calcium storage.

Usually only a few children serve as subjects, since the amount of work connected with a metabolism study is so great that only a limited number of children may be used. An extensive study on a few children may be more valuable than a short study on many children.

It is difficult to compare the results of one author with those of another, since the physiological condition of the children, type of diets used, and previous environ-

mental conditions, are variables which influence the study. This paper is given, therefore, to add to the available information on calcium balances of normal pre-school children on a constant normal diet.

Plan of Study

General Plan

This study consisted of two parts, a six day preliminary period and a twenty-four day test period during which the children received a constant diet containing 3.0 grams of protein and 92.0 calories per kilogram of body weight. Table II shows that the diet was adequate in all respects.

Two girls, J. H. and C. B. both aged three years and two boys, V. A. four years old and E. C. four and one-half years old served as subjects for this study. All of the children were apparently normal at the time of this experiment. Table III gives a comparison of the children's height and weight with the figures from Woodbury's Height-Weight-Age table (18). The variations of the height of the children from average values ranged from -4.16 to +3.44 per cent while fluctuations in their weights varied from -4.00 to +5.71 per cent. These percentages indicate that all of the children were within the normal range of average children. The children lived in an apartment in the Home Economics building. They were under constant supervision and maintained regular habits as to exercise, sleep, eating

TABLE II

COMPOSITION OF DIET AS CALCULATED*#

Food	Weight	Calories	Protein	Calcium
	gms.		gms.	gm.
Milk	800	552	26.40	0.960
Ralstons	20	72	0.89	0.004
Orange Juice	200	86	0.00	0.001
Beef (raw)	40	62	8.52	0.005
Eggs	40	59	5.36	0.027
Peaches	150	71	1.05	0.024
Applesauce	150	236	0.30	0.011
Celery	20	4	0.22	0.016
Beans	100	42	0.02	0.000
Tomatoes	100	23	0.01	0.000
Potatoes	80	66	1.76	0.012
Butter	20	154	0.20	0.003
Sugar	20	80	0.00	0.000
Bread	60	172	6.66	0.044
Total		1679	51.39	1.107

* Figures taken from Rose's Laboratory Handbook for Dietetics (13).

\# E. C. received the amount of food in table, V. A. received 0.90 this amount, C. B. received 0.80 this amount and J. H. received 0.75 this amount.

TABLE III

A COMPARISON OF THE HEIGHT AND WEIGHT

OF THE CHILDREN WITH THE FIGURES IN WOODBURY'S TABLES

Subject	Age	Height			Weight		
		Observed	Woodbury's Standard		Observed	Woodbury's Standard	
			Standard	Variation		Standard	Variation
	mos.	in.	in.	%	lbs.	lbs.	%
E. C.	54	42.88	43.00	-0.29	40.0	39.50	1.26
V. A.	48	40.25	42.00	-4.16	37.0	35.00	5.71
C. B.	36	38.75	38.00	1.97	32.0	32.75	-2.29
J. H.	36	37.50	36.25	3.44	30.0	31.25	-4.00

Left to right: J. H., V. A., E. C. and C. B.

and elimination. E. C. was ill during part of this study and it is questionable if the results after his illness are as dependable as those for the others. His results for periods 4, 5, 9, 10, and 11 were included in the study.

Duplicate food samples were weighed and made into a composite for future analysis. The food for a period of three days was simultaneously prepared, weighed into the container in which it was to be served and preserved in an ice box until used. The children ate all of the food served and the dishes were scraped and rinsed with a portion of their distilled water allotment.

Feces were collected in three day periods, carmine being used as a marker. Both the feces and the food samples were dried on a steam bath and then in an oven at 60 degrees C. until they were constant in weight. The dried samples were ground and seived to insure and even sample.

Urine specimens were collected in twenty-four hour samples. Triplicate aliquot portions were taken from each day's sample, combined into three day periods and dried on a steam bath.

Chemical Method: The food, feces, and urine samples were ashed and made into solution before they were used for analysis. Duplicate or triplicate portions of each dried food or feces sample were weighed directly into a platinum dish and ashed in a muffle furnace at a temperature below red heat. The ash was taken up in 25 per cent hydrochloric

acid, dehydrated and then dissolved in redistilled water. To insure complete solution a few drops of concentrated hydrochloric acid were added. This solution was filtered quanitatively into a 100 c.c. volumetric flask, made up to volume at 26 degrees C. and then stored in an air tight bottle. The dried urine samples were transferred quanitatively to a platinum dish, evaporated to dryness and ashed in the same manner as the food and feces samples.

Calcium was determined by Kramer and Howland's method (10). Five c.c. of saturated ammonium oxalate and five drops of .04 per cent brom cresol purple were added to a beaker containing an aliquot portion of the ash solution. The mixture was made alkaline with concentrated ammonium hydroxide and then acid with 5 normal hydrochloric acid. It was heated to a temperature just below the boiling point, cooled and adjusted to a pH of 6.2 by the addition of either 10 per cent ammonium hydroxide or 10 per cent acetic acid. The next day the precipitate was filtered by suction through a porous bottomed filter and washed with dilute ammonium hydroxide. The precipitate was dissolved in hot normal sulfuric acid with the addition of 5 to 25 drops of concentrated sulfuric acid. This solution was transferred quanitatively to the original beaker and titrated while hot with $KMnO_4$. Owing to the small amounts of calcium in the urine, N/100 $KMnO_4$ was used for titrating instead of N/20 $KMnO_4$ which was used in the analysis of the food and feces.

The accuracy of the method was checked by analyzing known solutions of pure calcium salts, feces samples which had previously been analyzed and feces samples to which a known amount of a calcium salt had been added. Table IV shows the results obtained from analysis of these solutions. For $CaSO_4$, all recoveries were 98.6 per cent or higher with an average of 99.7 per cent. The recovery of calcium from the two samples of $CaCl_2$ was slightly lower, ranging from 97.3 to 98.3 per cent with average recoveries of 97.6 and 97.8 per cent. This lower recovery may have been due to insufficient arging or to impurities in the sample. The Ca(CH)2 solutions gave the best recoveries, ranging from 98.9 to 99.5 per cent with averages of 99.1 and 99.4 per cent. The grams of calcium recovered from previously analyzed feces samples checked the former results within 2 per cent. When a known amount of pure calcium salt was added to feces samples, there was a recovery of from 98.6 to 99.7 per cent with averages of 99.2 and 99.7 per cent. The above results indicate that the method was accurate within 2 per cent.

TABLE IV

ACCURACY OF THE METHOD BY ANALYSES OF

KNOWN SOLUTIONS AND PREVIOUSLY ANALYZED FECES SAMPLES

Series	Sample	Number of Determinations	Calcium calculated	Calcium Recovered		
				Amount	Per Cent	Average Per Cent
			mgs.	mgs.		
I	$CaSO_4$	6	2.15	2.122	98.6	98.7
				2.126	98.9	
				2.123	98.7	
				2.125	98.8	
				2.121	98.6	
				2.127	98.9	
	$CaCl_2$	3	3.47	3.379	97.4	97.6
				3.396	97.9	
				3.385	97.6	
				3.389	97.6	
				3.376	97.3	
		4	2.37	2.325	98.2	97.8
				2.320	97.9	
				2.309	97.4	
				2.309	97.4	
	$Ca(CH)_2$	3	3.41	3.376	99.0	99.1
				3.382	99.2	
				3.377	99.0	
		2	3.47	3.448	99.3	99.4
				3.452	99.5	
II	Feces	2	6.02	6.009	99.8	99.8
				6.003	99.7	
		1	7.80	7.771	99.6	99.6
		1	10.82	10.926	100.9	100.9
		1	7.74	7.772	100.4	100.4
		1	7.68	7.558	98.4	98.4
		2	9.11	9.140	100.3	100.2
				9.132	100.1	
III	Feces	2	6.02	9.446	98.8	99.2
	$Ca(CH)_2$		3.47	9.452	99.6	
	Feces	5	9.11	12.552	99.7	99.7
	$Ca(CH)_2$		3.47	12.547	99.7	
				12.543	99.7	
				12.540	98.6	
				12.534	98.6	

Discussion of Results

Variation in Diet Analysis

The variations of the analyzed food samples and the calculated amount of calcium in the diet are shown in Table V and Graph I. It will be noted that the difference between the mean of the analyzed samples and the mean of the computed calcium was 2.33 per cent. Donelson and others (6) reported a similar mean difference of 3.6 per cent between calculated and analyzed values, Bray, Hawks and Dye (2) a difference of 4.9 per cent and Bassett and co-workers (1) found that the variations for a high and a low calcium diet were -9.7 and -32.6 per cent. In this study the difference from period to period between the observed and computed calcium ranged from 0.064 to 6.73 per cent. Donelson and co-workers found a variation of from 0.0 to 22.0 per cent and Bray and others found a difference between analyzed and computed values of different diets, ranging from -45.7 to 27.3 per cent. Therefore, it appears that the percentage variation between the computed and the anayzed values in this study was no greater than that observed by other investigators. Graph I shows that the variation between duplicate samples, collected on the same day and designated as A and B, was in some cases almost as large as the difference between the observed and calculated values. In some cases the duplicate samples checked almost exactly and in one case the variation was as large as 4.24 per cent.

The difference between A and B samples and their mean analyzed value was as high as 5.17 per cent which was greater than any observed variations between A and B samples on the same day. The variation in the calcium content of the food is possibly due to unavoidable errors in the preparation and analysis of the food as well as to the variation in its composition. Although every effort was made to have a homogenous sample and duplicate samples for analysis were weighed under identical conditions and at the same time that the food for the children was weighed, there were still variations. Thus the calcium content of the food the children received may have varied as much as the analyzed samples.

Calcium Balances per Day: The variations in the amounts of calcium consumed from period to period by each child were in proportion to those discussed above. Since the calcium ingested was based on the child's weight, the amount of calcium consumed by each child differed greatly, ranging from 0.724 to 0.780 gram for J. H. and from 1.033 to 1.099 grams for E. C. (Table VI). Because of this variation, the utilization of the total calcium can most readily be compared in terms of per cent of the intake, therefore, the percentage figures are also included.

That a small and fairly constant amount of calcium was excreted in the urine is shown in Table VI and Graph II. It will be noted that the daily variation for J. H. was the greatest, ranging from 0.026 to 0.044 gram per day, while

TABLE V

COMPARISON OF CALCULATED AND ANALYZED VALUES OF CALCIUM IN FOOD*#

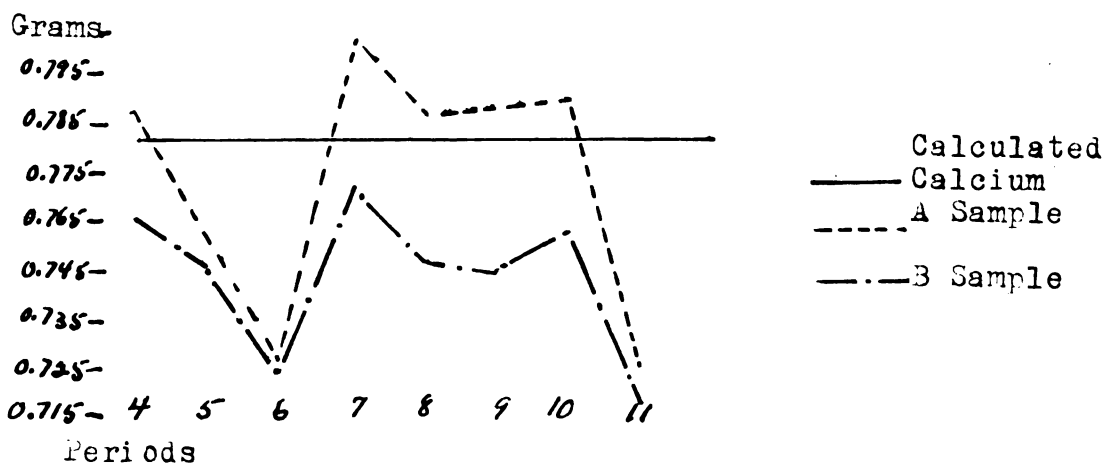
Period	Calcium calculated	Calcium Analyzed Sample A	Sample B	Average of A&B Sample	Per Cent Variation Between Cal. and av. analyzed Value	A&B Samples	Mean Analyzed Value and Sample A	B
	gm.	gm.	gm.	gm.	%	%	%	%
4	0.773	0.779	0.757	0.768	0.64	2.82	3.18	0.26
5	0.773	0.775	0.748	0.752	2.72	0.93	0.00	0.93
6	0.773	0.726	0.725	0.726	6.08	0.14	3.84	3.97
7	0.773	0.793	0.763	0.778	0.64	3.78	5.03	1.06
8	0.773	0.779	0.748	0.764	1.16	3.98	3.18	0.93
9	0.773	0.779	0.746	0.763	1.29	4.24	3.18	1.19
10	0.773	0.781	0.753	0.767	0.78	3.59	3.44	0.26
11	0.773	0.726	0.716	0.721	6.73	1.38	3.84	5.17
Mean	0.773			0.755	2.53			

* Calculated values are taken from Rose's tables (13).

\# The figures in this Table are for J. H.

GRAPH I

COMPARISON OF CALCULATED AND ANALYZED VALUES FOR FOOD



that of C. B. was the smallest, ranging from 0.016 to 0.025 gram. The per cent of the intake excreted was lowest in all cases for E. C. (0.5 to 1.8%) and highest for J. H. (3.5 to 6.1%).

The amount of calcium excreted in the feces was much greater than that in the urine, ranging from 0.592 to 0.968 gram per day, and in some cases was in proportion to the intake. This is clearly demonstrated by the comparisons in Graph II. The variation from period to period in terms of percentage of intake show that the fluctuation for V. A. was greatest, ranging from 76.5 to 94.9 per cent, and that of J. H. the least, ranging from 78.5 to 87.7 per cent. The daily variation was greater for E. C. than for C. B.

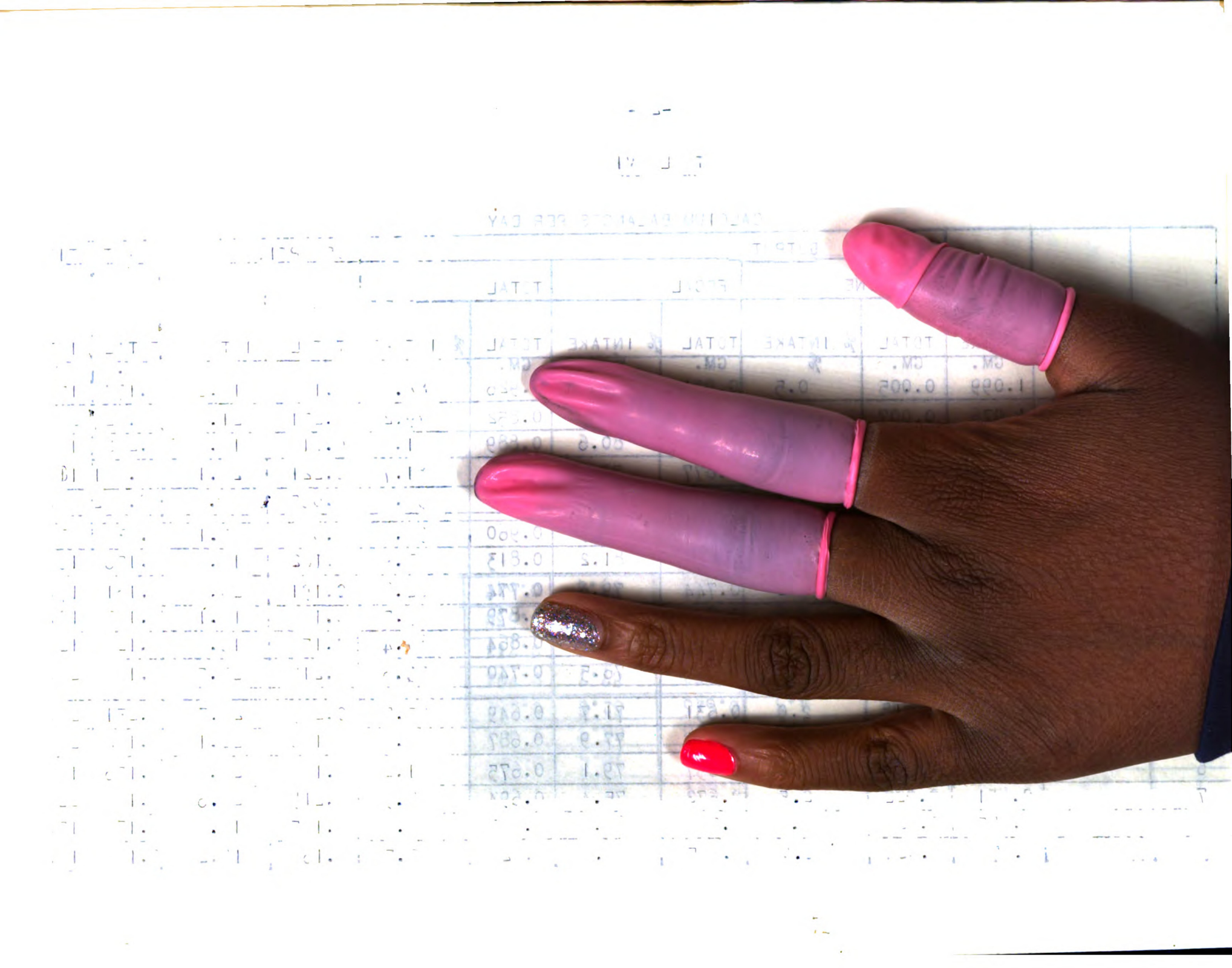
The fluctuations in the total output were largely due to the variations in the fecal calcium, since the urinary calcium was small and fairly constant. The total excretion varied from 0.627 to 0.961 gram per day being greater for the larger children. The per cent of the intake excreted ranged from 73.7 to 97.0 per cent but was not always in proportion to size (Table VI).

A large variation in the absorption from period to period was noticed for each child, ranging from 0.050 to 0.249 gram per day. The per cent of the intake absorbed varied from 5.1 to 28.3 per cent (Table VI). The fluctuation was greatest for V. A. and least for J. H. Graph II shows that the amount of calcium excreted in the urine was

TABLE VI

CALCIUM BALANCES PER DAY

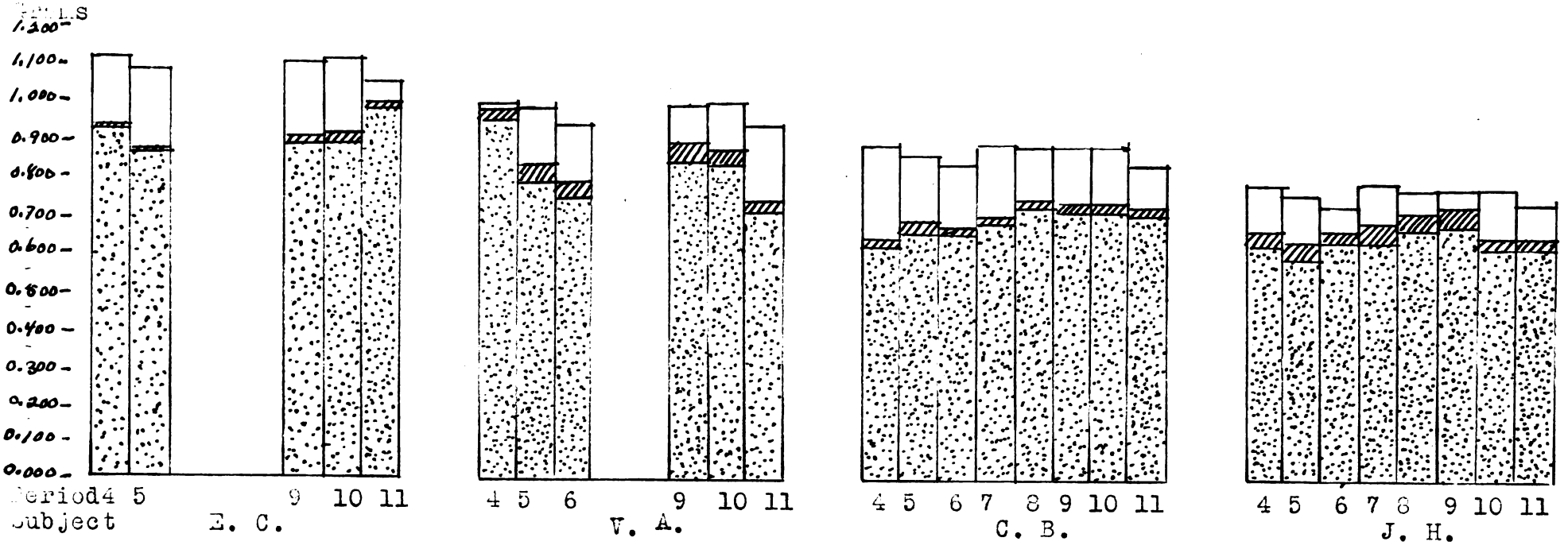
PERIOD	SUBJECT	INTAKE	OUTPUT						ABSORPTION		RETENTION	
			URINE		FECAL		TOTAL					
			TOTAL	% INTAKE	TOTAL	% INTAKE	TOTAL	% INTAKE	TOTAL	%INTAKE	TOTAL	%INTAKE
		GM.	GM.	%	GM.	%	GM.	%	GM.	%	GM.	%
4	E.C.	1.099	0.005	0.5	0.921	83.8	0.926	84.3	0.178	16.2	0.173	15.7
5		1.076	0.007	0.7	0.845	78.5	0.852	79.2	0.231	21.5	0.224	20.8
9		1.091	0.010	0.9	0.879	80.6	0.889	81.5	0.212	19.4	0.202	18.5
10		1,098	0.020	1.8	0.877	79.9	0.897	81.7	0.221	20.1	0.201	18.3
11		1.033	0.013	1.3	0.968	93.7	0.981	95.0	0.065	6.3	0.052	5.0
4	V.A	0.990	0.020	2.1	0.940	94.9	0.960	97.0	0.050	5.1	0.030	3.0
5		0.969	0.026	2.7	0.787	81.2	0.813	83.9	0.182	18.8	0.156	16.1
6		0.935	0.030	3.2	0.744	79.6	0.774	82.8	0.191	20.4	0.161	17.2
9		0.982	0.035	3.6	0.844	85.9	0.879	89.5	0.138	14.1	0.103	10.5
10		0.988	0.034	3.4	0.833	84.0	0.864	87.4	0.158	16.0	0.124	12.6
11		0.930	0.029	3.1	0.711	76.5	0.740	79.6	0.219	23.5	0.190	20.4
4	C.B	0.880	0.018	2.0	0.631	71.7	0.649	73.7	0.249	28.3	0.231	26.3
5		0.861	0.016	1.9	0.671	77.9	0.687	79.8	0.190	22.1	0.174	20.2
6		0.831	0.018	2.1	0.657	79.1	0.675	81.2	0.174	20.9	0.156	18.8
7		0.891	0.022	2.5	0.672	75.4	0.694	77.9	0.219	24.6	0.197	22.1
8		0.875	0.023	2.6	0.720	82.3	0.743	84.9	0.155	17.7	0.132	15.1
9		0.873	0.024	2.7	0.705	80.8	0.729	83.5	0.168	19.2	0.144	16.5
10		0.879	0.025	2.8	0.711	80.9	0.736	83.7	0.168	19.1	0.143	16.3
11		0.827	0.023	2.8	0.693	83.8	0.716	86.6	0.134	16.2	0.111	13.4
4	J.H	0.770	0.033	4.3	0.621	80.6	0.654	84.9	0.149	19.4	0.116	15.1
5		0.754	0.035	4.7	0.592	78.5	0.627	83.2	0.162	21.5	0.127	16.8
6		0.728	0.026	3.5	0.628	86.3	0.654	89.8	0.100	13.7	0.074	10.2
7		0.780	0.035	4.5	0.646	82.8	0.681	87.3	0.134	17.2	0.099	12.7
8		0.766	0.032	4.2	0.672	87.7	0.704	91.9	0.094	12.3	0.062	8.1
9		0.765	0.041	5.4	0.671	87.7	0.712	93.1	0.094	12.3	0.053	6.9
10		0.769	0.034	4.5	0.604	78.5	0.638	83.0	0.165	21.5	0.131	17.0
11		0.724	0.044	6.1	0.604	83.4	0.648	89.5	0.120	16.6	0.076	10.5



GRAPH II

CALCIUM BALANCES PER DAY

Entire column Total Intake
Urinary excretion
Fecal excretion
Retention
Absorption



small, since practically all of the absorbed calcium was retained. The daily retentions for E. C. and V. A. varied from 0.052 to 0.224 gram and from 0.030 to 0.190 gram respectively. The retentions for J. H. and C. B. whose fecal outputs were the most constant, ranged from 0.053 to 0.131 and from 0.111 to 0.231 gram per day respectively. It will be noted that all retentions were positive. On the basis of the per cent of the intake retained these values for all children ranged from 3.0 to 26.3. It will be noted that the daily percentage fluctuations were greatest for V. A. and least for J. H.

Average Calcium per day: While the above figures show that there were large period by period variations in calcium balance, the average values would indicate the general trend of the calcium metabolism. The average intakes according to size were 1.079, 0.966, 0.865 and 0.757 grams per day (Table VII). It will be noted that although the amounts were small, there was a considerable difference in the urinary calcium excreted by different children. The largest child excreted the least, 0.011 gram per day or 1.0 per cent and the smallest child the most, 0.035 gram or 4.6 per cent. This was not inversely proportionate to size, however, since V. A. excreted 0.029 gram per day while C. B. excreted only 0.021 gram. It is interesting to note that although the average amounts of fecal calcium excreted ranged from 0.630 to 0.898 gram per day, the percentage of the intake excreted

TABLE VII

AVERAGE CALCIUM BALANCES PER DAY

Subject	In-take	Output						Retention		Absorption	
		Urine	Per Cent	Feces	Per Cent	Total Output	Per Cent	Total	Per Cent	Total	Per Cent
	gm.	gm.		gm.		gm.		gm.		gm.	
E. C.	1.079	0.011	1.0	0.898	83.2	0.909	84.2	0.170	15.7	0.181	16.7
V. A.	0.966	0.029	3.0	0.809	83.7	0.838	86.7	0.127	13.3	0.156	16.3
C. B.	0.865	0.021	2.4	0.683	78.8	0.704	81.4	0.161	18.6	0.182	21.1
J. H.	0.757	0.035	4.6	0.630	83.2	0.665	87.8	0.092	12.2	0.127	16.8
Av.	0.917	0.024	2.8	0.755	82.2	0.779	85.0	0.138	15.0	0.168	17.7

was exceedingly constant. It was 83 per cent for all of the children with the exception of C. B. for whom it was 78.8 per cent of the intake, Since the per cent of the fecal calcium was practically constant for three of the children, the variation in the total output was largely due to that of the urinary calcium. These percentages were less constant than the fecal output and varied from 81.4 to 87.8 per cent of the intake. Table VII shows that the amount of calcium absorbed ranged from 0.127 to 0.182 gram per day. All of the children absorbed about 16 per cent of the intake with the exception of C. B. who absorbed more due to the lower per cent of calcium excreted in the feces. The amount of calcium stored varied from 0.092 to 0.170 gram per day and the amount retained was in proportion to the size of the child except for V. A. who stored less than either E. C. or C. B. The children retained from 12.2 to 18.6 per cent of the intake with an average of 15 per cent.

Calcium Balances per Kilogram: When the results are compared on the basis of body weight, the intake range for all of the children was from 0.053 to 0.061 gram per kilogram. Although the values for each child varied from period to period in the same general manner as the total calcium, intake, Table VIII and Graph III show that the intake for each child was fairly constant on this basis. The greatest difference between the intake values for any one child was only 0.004 gram.

On the kilogram basis, each child excreted an almost constant amount of urinary calcium and in no case was the fluctuation greater than 0.001 gram per kilogram per day. J. L. was the only child who excreted as much as 0.103 gram per day (Table VIII). It may be that the amount of urinary acidity had some relationship to the amount of calcium present in the urine, therefore, it seemed advisable to compare these values (Table IX). Apparently there was no appreciable relationship between them, since in only two cases was the correlation as high as 0.5 (0.50 for V. A. and -0.53 for E. C.).

Table VIII and Graph III show that the amount of calcium excreted in the feces for all of the children ranged from 0.042 to 0.086 gram per kilogram and that the daily variations were highest for V. A. and lowest for C. B. and J. H. This fluctuation was not much greater than was the variation in the intake, except in the case of V. A. Nevertheless, the values did not always vary in the same manner. The fluctuations in the fecal output were probably due, to some extent, to unavoidable errors in the collection of samples and other uncontrollable conditions. Some of these may be variations in the conditions in the intestinal tract, such as constipation which may hold the food in the intestinal tract for an abnormal period of time and thus increase calcium absorption. On the other hand, diarrhea may hasten the food through the tract so rapidly that there may not be

TABLE VIII

CALCIUM BALANCES PER KILOGRAM OF BODY WEIGHT PER DAY

PERIOD	WEIGHT	SUBJECT	INTAKE	OUTPUT		TOTAL	RETENTION	ABSORPTION
				URINE	FECES			
	KG		GM	GM	GM	GM	GM	GM
4	18.42	E.C.	0.060	0.000	0.050	0.050	0.009	0.010
5	18.42		0.058	0.000	0.046	0.046	0.012	0.013
9	18.28		0.060	0.001	0.048	0.049	0.011	0.012
10	18.28		0.060	0.001	0.048	0.049	0.011	0.012
11	18.28		0.057	0.001	0.053	0.054	0.003	0.004
4	16.90	V.A.	0.059	0.001	0.056	0.057	0.002	0.003
5	16.97		0.057	0.002	0.046	0.048	0.009	0.011
6	17.05		0.055	0.002	0.044	0.045	0.009	0.011
9	17.12		0.057	0.002	0.049	0.051	0.006	0.008
10	17.08		0.058	0.002	0.049	0.051	0.007	0.009
11	17.05		0.055	0.002	0.042	0.043	0.011	0.013
4	14.47	C.B.	0.061	0.001	0.044	0.045	0.016	0.017
5	14.55		0.059	0.001	0.046	0.047	0.012	0.013
6	14.55		0.057	0.001	0.045	0.046	0.011	0.012
7	14.55		0.061	0.002	0.046	0.048	0.014	0.015
8	14.66		0.060	0.002	0.049	0.051	0.009	0.011
9	14.66		0.060	0.002	0.048	0.050	0.010	0.011
10	14.62		0.060	0.002	0.049	0.050	0.010	0.011
11	14.62		0.057	0.002	0.047	0.049	0.008	0.009
4	13.56	J.H.	0.057	0.002	0.046	0.048	0.009	0.011
5	13.60		0.055	0.003	0.044	0.046	0.009	0.012
6	13.64		0.053	0.002	0.046	0.048	0.005	0.007
7	13.64		0.057	0.003	0.047	0.050	0.007	0.010
8	13.64		0.056	0.002	0.049	0.052	0.005	0.007
9	13.64		0.056	0.003	0.049	0.052	0.004	0.007
10	13.64		0.056	0.002	0.044	0.047	0.010	0.012
11	13.67		0.053	0.003	0.044	0.047	0.006	0.009

GRAPH III

CALCIUM BALANCES PER KILOGRAM OF BODY WEIGHT PER DAY

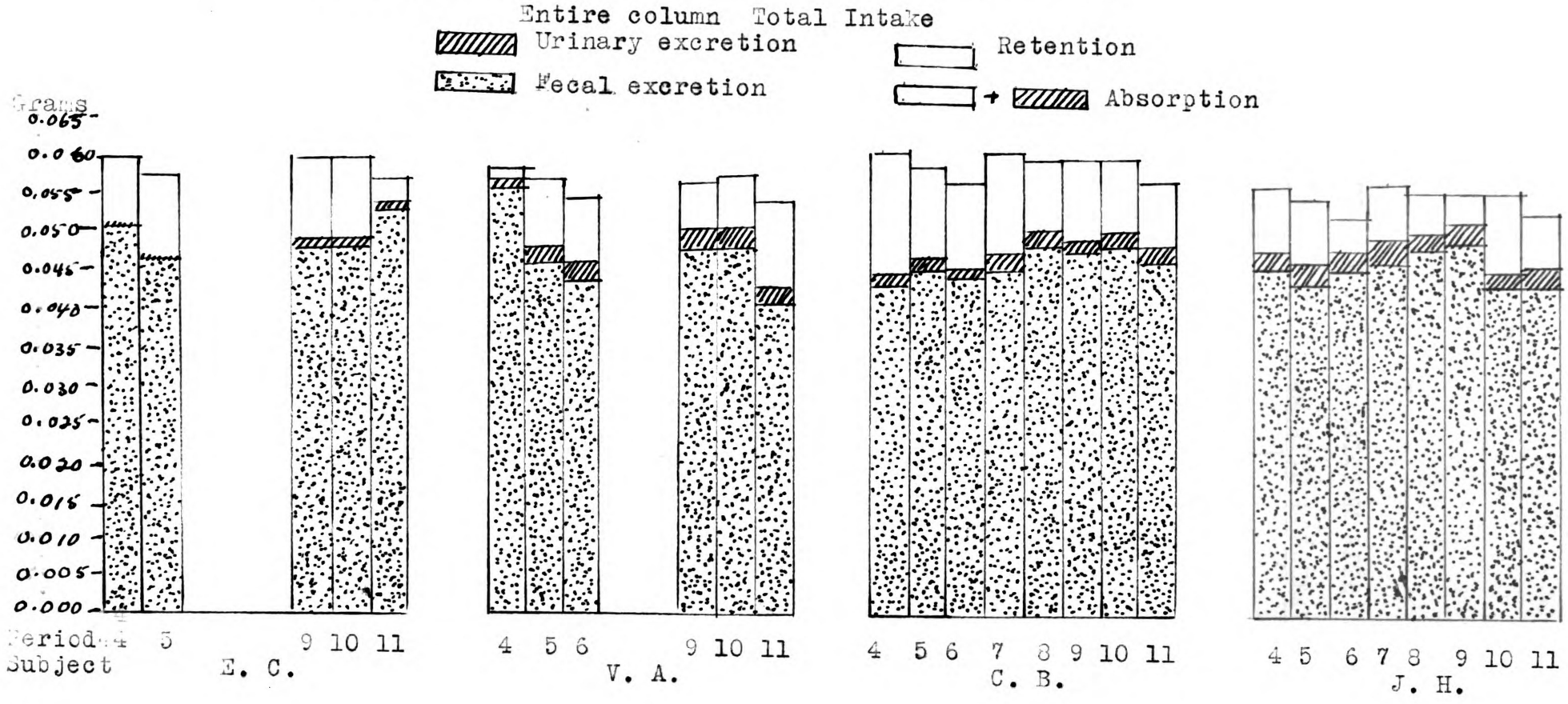


TABLE IX

COMPARISON OF URINARY CALCIUM WITH

URINARY ACIDITY PER MILLIGRAM WITH CORRELATIONS

Subject	Period	Correlation	Calcium	Acidity
			gm.	gm.
E. C.	4	-0.527	0.0003	8.5
	5		0.0004	8.5
	9		0.0005	7.8
	10		0.0011	7.8
	11		0.0007	8.5
V. A.	4	0.437	0.0012	5.6
	5		0.0015	6.4
	8		0.0011	6.0
	9		0.0016	6.8
	10		0.0020	7.0
	11		0.0017	5.7
C. B.	4	0.502	0.0012	4.9
	5		0.0011	5.8
	6		0.0012	6.1
	7		0.0015	6.9
	8		0.0016	7.4
	9		0.0016	6.8
	10		0.0017	6.2
	11		0.0016	6.0
J. H.	4	0.022	0.0024	7.1
	5		0.0026	7.3
	6		0.0019	6.3
	7		0.0026	6.3
	8		0.0023	6.1
	9		0.0030	7.0
	10		0.0025	5.2
	11		0.0032	6.0

time for sufficient absorption. The acid condition of the intestinal tract may also affect the amount of calcium absorbed.

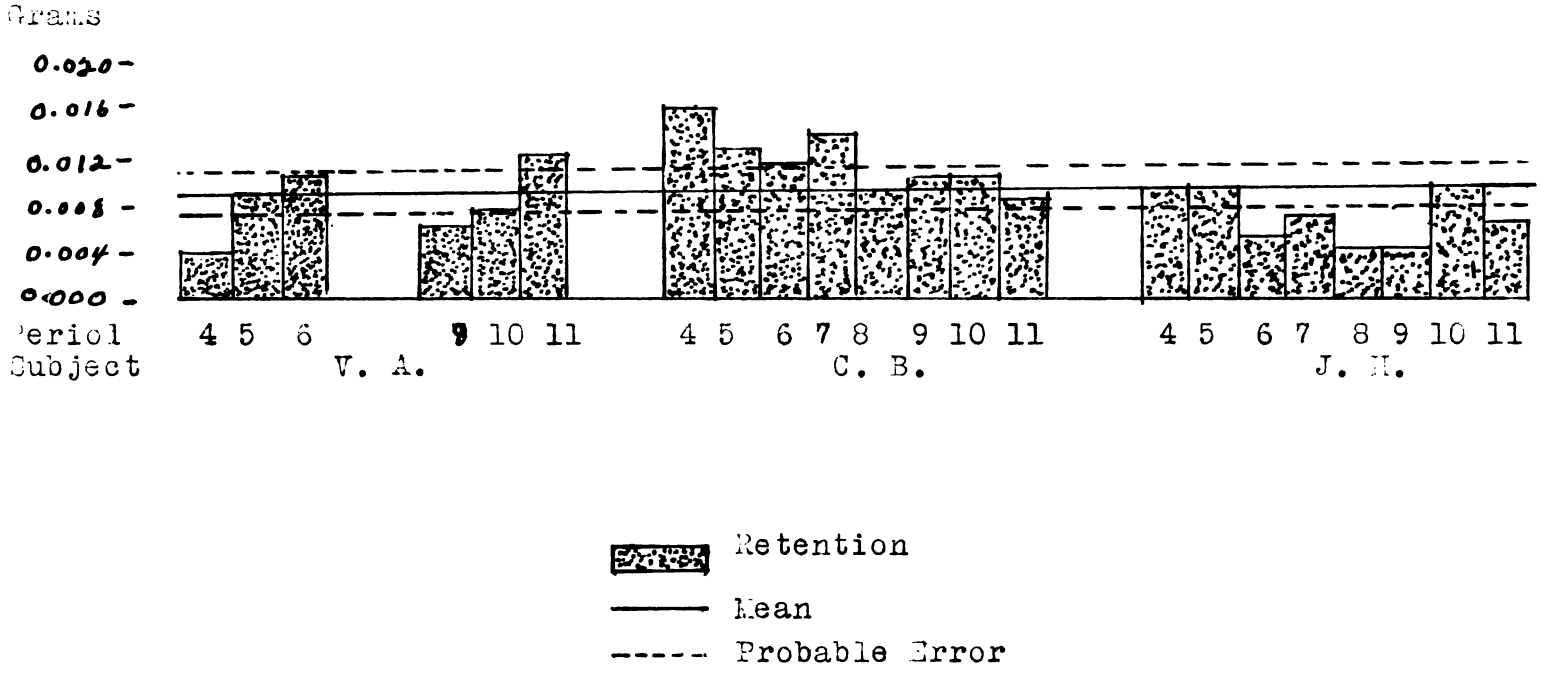
Table VIII and Graph III show that the total amount of calcium excreted for all of the children varied from 0.043 to 0.057 gram per kilogram of body weight. The variation between the highest and lowest amounts excreted per child was 0.008 gram for E. C., 0.014 for V. A., and 0.006 for C. B. and J. H. This was, of course, in direct proportion to the fecal output, since the amount of calcium excreted in the urine was so small.

The amount of calcium absorbed ranged from 0.003 to 0.017 gram per kilogram of body weight. The greatest variation in absorption noted for any of the children was for V. A., ranging from 0.003 to 0.013 gram, and the least was for J. H., varying from 0.007 to 0.012 gram. The fluctuation in the amount of calcium absorbed is illustrated in Graph III

Since there was such a small amount of urinary calcium, the retention varied in direct proportion to the absorption as shown in Graph III. It will be noted that the fluctuations varied from period to period, ranging from 0.002 to 0.016 gram per kilogram of body weight. The variation was greatest for V. A. and least for J. H. Graph IV shows distinctly the daily amount of calcium per kilogram retained by the three children. It also gives the mean for all of

GRAPH IV

RETENTION VALUES PER KILOGRAM OF BODY WEIGHT



the children which is 0.009 with a probable error of ±0.002 gram. Since there are so many unavoidable variations and since the values are so small, the figures are in reality quite constant for each child and even for all of the children.

The relationships between these data per kilogram may be better interpreted by means of statistical treatment. (Table X). The correlation between the intake and fecal output was only 0.35 showing that there was practically no relationship between them. There was, likewise, no definite relationship between the calcium intake and the retention as is shown by a correlation of 0.43. It must be considered, however, that there were only 22 cases and that individual errors were great. If there had been a larger volume of data or if the range in intake had been greater, the correlations might have been higher. On the other hand, a direct relationship was shown between the fecal and total outputs by a correlation of 0.93. There was, also, a definite correlation of 0.90 between the absorption and retention.

Average Calcium Balances per Kilogram: The average calcium balances per kilogram for each child give a more complete picture of the metabolic tendencies (Table XI). The average intake was practically the same for each child, ranging from 0.056 to 0.059 gram per day with an average for all of the children of 0.058 gram. The average urinary

TABLE X

CORRELATIONS*

	Fecal Output	Retention
Intake	0.35	0.43
Total Output	0.93	
Absorption		0.90

* Figures for E. C. not included.

calcium ranged from 0.001 to 0.003 gram per kilogram, that of E. C. being the least and that of J. H. the most. C. B. and V. A. excreted the same quanity of urinary calcium (0.002 gram). As has been noted before, the urinary calcium excretion was very small in proportion to the fecal output which was practically the same for all of the children, ranging from 0.046 to 0.049 gram per kilogram of body weight. The fact that the average amount of fecal calcium was practically the same for all of the children may indicate that a long continuous period removes differences and eradicates the errors. The average total output was 0.049 gram per kilogram of body weight for all of the children, with the exception of E. C. whose average total output was 0.050 gram.

Table XI shows that V. A. and J. H. absorbed the least calcium (0.009 gram per kilogram) and C. B. the most (0.012 gram). The average calcium retentions were also lowest for J. H. and highest for C. B. ranging from 0.007 to 0.011 gram per kilogram. The retentions for E. C. and V. A. were 0.009 and 0.008 gram per kilogram respectively. The difference between the highest and lowest amounts absorbed and retained were certainly values which might be within experimental error. Considering the variations which occurred, it is interesting to note that these values for calcium were so constant for all of the children.

When the calcium balances are compared as a whole, it will be noted that the intakes for E. C. and C. B. were

TABLE XI

AVERAGE CALCIUM BALANCES PER KILOGRAM PER DAY

Weight	Subject	Intake	Output			Absorption	Retention
			Urine	Feces	Total		
kg.		gm.	gm.	gm.	gm.	gm.	gm.
18.34	E. C.	0.059	0.001	0.049	0.050	0.010	0.009
17.03	V. A.	0.057	0.002	0.048	0.049	0.009	0.008
14.59	C. B.	0.059	0.002	0.047	0.049	0.012	0.011
13.63	J. H.	0.056	0.003	0.046	0.049	0.009	0.007
15.90	Av.	0.058	0.002	0.048	0.049	0.010	0.009

highest and that their retentions and absorptions were slightly higher than those of the other two children. Both the intake and retention were lowest for J. H. From these results it appears that there might be some relationship between the calcium intake and retention. The amount of urinary and fecal calcium may have an inverse relationship, since the child with the greatest fecal output had the smallest urinary excretion and vice versa. There also may be some relationship between age and utilization because E. C., the oldest child, absorbed as much or more calcium than the smaller children and excreted a smaller amount in the urine. The youngest child absorbed practically the same amount of calcium but excreted a larger amount in the urine. The urinary calcium decreased as the age of the child increased. Although there was a variation in the amounts of both urinary and fecal calcium, the total calcium output was practically the same for all of the children. There are too few cases to draw any definite conclusions.

Comparison with a Former Study: A previous metabolism study was conducted under practically the same conditions. Two children D. A. and W. W., both four and one-half years of age, served as subjects for the investigation. Table XII shows the average results obtained per kilogram of body weight. When the results of the two studies are compared, it will be noted that the intake for D. A. and W. W. was somewhat higher (0.065 gram) than that in this

study. The urinary calcium was higher for D. A. (0.005 gram) than that noted for any of the children in this study while that for M. M. was practically the same (0.002 gram per kilogram). The amount of calcium excreted in the feces was greater for D. A. and M. M. than for the four children in this study, probably due to the higher intake. The absorption for D. A. was 0.010 gram which was within the range of that noted in this study while M. M. only absorbed 0.005 gram. The average retentions for D. A. and M. M. were 0.005 and 0.003 gram per kilogram respectively, both of which were less than those observed in this study (0.009 to 0.012 gram).

Comparison with Studies of Other Investigators: A comparison of this study with those of other investigators is difficult because the studies varied in so many respects. In some cases the intakes were much higher than in this study, in others the source of Vitamin D, the length of the period or the condition of the children were limiting factors. Taking the fact that there are many variables into consideration, a comparison may be made between this study and others in which the intake was 0.058 ± 0.005 gram per kilogram of body weight and in which the children were practically the same age (Table XIII).

Sherman and Lawley (14) reported two cases in one of which the intake was 0.083 gram and the output 0.042 gram and in the other the intake was 0.067 gram and the output

TABLE XII

AVERAGE CALCIUM BALANCES PER KILOGRAM OF BODY WEIGHT*

Subject	Intake	Output			Absorption		Retention	
		Urine	Feces	Total	Total	Per Cent	Total	Per Cent
	gm.	gm.	gm.	gm.	gm.		gm.	
D. A.	0.065	0.005	0.055	0.060	0.010	15.6	0.005	8.4
W. W.	0.065	0.002	0.060	0.062	0.005	7.2	0.003	4.6
Av.	0.065	0.004	0.058	0.061	0.008	11.4	0.004	6.5

*Figures from Miller's Thesis (8).

TABLE XIII

CALCIUM BALANCE STUDIES BY OTHER INVESTIGATORS

WITH AN INTAKE FROM 0.053 TO 0.063 GRAM PER KILOGRAM

	Children				Retention	
Investigator	Age	No.	Intake	Total Output	Total	Per Cent
	yrs.		gm.	gm.	gm.	
Sherman-Hawley	3-5	3	0.053	0.042	0.010	19.3
	4-5	2	0.063	0.049	0.014	23.2
Wang (16)	5	1	0.061	0.049	0.012	19.0
	4-5	2	0.061	0.042	0.019	31.0
Hawks	4-5	3	0.061	0.054	0.008	13.1
	4-5	3	0.057	0.042	0.015	26.3
Porter-Levin	2½-5½	3	0.054	0.047	0.007	12.9
Daniels (5)	4½	1	0.054		0.012	22.2
	3	1	0.054		0.009	16.7
	5	1	0.054		0.008	14.8
	4	1	0.057		0.007	12.3

0.049 gram per kilogram. The retentions were 0.010 and 0.014 gram respectively. In this study the intake was 0.058 gram with an output of 0.049 gram and a retention of 0.009 gram. Hawks and others (15) reported two cases in which the intake was 0.061 gram per kilogram. In one the output was 0.049 gram while in the other it was 0.042 gram per kilogram. The retentions were 0.012 and 0.019 gram respectively both of which were slightly higher than the average found in this study. Hawks and co-workers (7) found that the calcium storage for intakes of 0.061 and 0.057 gram was 0.008 and 0.015 gram per kilogram respectively. In all of these cases the retentions varied somewhat from those observed in this study. Nevertheless, the amount of calcium stored was within the range of this study.

It seemed worth while to compare this study with others which were continued for longer periods of time. Porter-Levin (12) found an output of 0.047 gram and a retention of 0.007 gram when the intake was 0.054 gram per kilogram of body weight. In the report which Daniels and others (5) give, there were three cases when the intake was 0.054 gram and one case when it was 0.057 gram per kilogram. The retentions were 0.012, 0.009, 0.008 and 0.007 gram per kilogram respectively. They also reported that calcium retentions between 0.007 and 0.009 gram per kilogram seemed to be normal for well developed children of pre-school age regardless of the intake. The results of this study confirm the work of

others and it appears that these normal pre-school children retained approximately 0.009 gram per kilogram when the intake was within the range of 0.056 to 0.059 gram per kilogram of body weight.

Summary

1. This study presents the calcium metabolism values of four normal children who received a constant medium protein diet for twenty-four consecutive days following a six day preliminary period.

2. The plan of this study was so arranged that the children received approximately the same amount of calcium per kilogram of body weight per day.

3. Although the diets were supposed to be identical, there was as much as 5.17 per cent variation between the chemical analysis of these samples. Thus the calcium intake per day for each child varied somewhat.

4. Since the amount of calcium excreted in the urine was very small and constant and since the quanity of calcium excreted from period to period in the feces was large and irregular in amount, the variations in the absorption and retention were largely influenced by the fluctuations in the intake and fecal output.

5. The percentage of calcium intake excreted in the feces was very constant for all of the children, ranging from 78.8

to 83.7. On this same basis, the average retentions ranged from 12.2 to 18.6 per cent.

6. The calcium intake and output per kilogram of body weight were fairly constant from period to period and the retention ranged from 0.002 to 0.016 gram per kilogram for all of the children.

7. The average values for the calcium intake and output per kilogram were practically the same for all of the children. The intake varied from 0.056 to 0.059 gram and the largest intakes were accompanied by the largest retentions which ranged from 0.007 to 0.011 gram. The average calcium storage per kilogram of body weight was 0.009 gram.

8. The retentions reported in this study were within the same general range as those reported by other investigators in which the calcium intake was 0.058 0.005 gram.

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