CALCIUM METABOLISM OF INFANTS AND YOUNG CHILDREN AND THE RELATION OF CALCIUM TO FAT EXCRETION IN THE STOOLS

PART 2.—CHILDREN TAKING A MIXED DIET *

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In a preceding paper on calcium metabolism was considered the absorption of calcium by infants taking modifications of cow's milk and the excretion of calcium in relation to the excretion of fat in their stools. In this paper we discuss the calcium metabolism of older children taking a mixed diet. As stated in the previous paper, by calcium *excretion* is meant the total amount of calcium lost in the stools; whether part of this has been absorbed and is subsequently excreted into the large intestine is not here considered. By calcium *absorption* is meant the difference between intake and the amount lost in the stools.

HEALTHY CHILDREN

The first group considered includes children who were normal as to digestion. Tables 1 and 2 show the calcium absorption in relation to calcium and fat intake for normal children taking a mixed diet; Table 1 including the cases in which the intake of calcium oxid was high, and Table 2 those in which it was low. The values are expressed as grams per kilogram of body weight.

Calcium Absorption and Its Relation to Calcium Intake.—Excluding two unusually high values and one unusually low value, the intake of calcium oxid per kilo ranged from 0.043 to 0.178 gm., with an average of 0.108 gm. In only about one half the cases was the intake more than 0.1 gm. per kilo. The children taking a mixed diet had, on the whole, a much lower intake of calcium oxid per kilo than those who were taking modifications of cow's milk.

The absorption of calcium oxid per kilo also was much lower than was found with the infants; it ranged from 0 to 0.147 gm. of calcium oxid per kilo, the two highest values being found when the intake was exceptionally high.

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* In the article published in the February issue of the AMERICAN JOURNAL OF DISEASES OF CHILDREN, p. 112, an error was made in the fourth line of the first paragraph of the Summary. The figure 0.6 gm. should read 0.06 gm.

TABLE 1.—ABSORPTION OF CALCIUM BY HEALTHY CHILDREN TAKING A MIXED DIET, WITH AN INTAKE OF CALCIUM OXID EXCEEDING 0.09 GM. PER KILO

No.	Case	Age Yr. Mo.	Weight in Gm.	Stools	Intake of CaO Gm. per Kg.	CaO Absorbed Gm. per Kg.	Per- centage of CaO Intake absorbed	Intake of Fat Gm. per Kg.	Grams CaO Intake per Gm. Fat Intake	Remarks
321	F. S.	1 6	8,975	Constipated	0.244	0.147	60.4	6.8	0.086	Very high calories per kilogram
325	H. F. 1	1 0	7,136	Constipated	0.237	0.115	48.4	4.9	0.048	
327	H. F. 3	1 0	7,749	Constipated	0.178	0.087	10.1	4.7	0.038	High calories per kilogram, high proportion carbohydrate
318	D. L.	1 2	8,264	Constipated	0.176	0.087	49.6	4.1	0.043	
267	O. W. 1	2 6	9,968	Normal	0.175	0.081	46.3	3.8	0.046	
268	O. W. 2	2 7	10,280	Constipated	0.171	0.107	63.1	3.7	0.046	
364	O. W. 4	2 7	10,546	Normal	0.170	0.104	61.4	4.5	0.038	Skimmed milk with corn oil
379	H. F. 4	1 1	8,218	Normal	0.167	0.095	15.2	4.5	0.087	Nut butter
269	O. W. 5	2 8	10,714	Constipated	0.165	0.103	62.5	5.0	0.083	Cod liver oil
308	H. F. 5	1 1	8,455	Constipated	0.163	0.083	20.3	4.2	0.039	Fat-free milk, milk butter
380	H. F. 6	1 2	8,790	Normal	0.157	0.081	32.6	4.0	0.039	Fat-free milk, nut butter
225	C. A. 1	2 3	11,860	Normal	0.156	0.083	14.6	2.9	0.053	Whole milk only. Low total calories
312	R. K. 3	2 0	11,510	Normal	0.153	0.081	52.8	3.3	0.046	
233	F. W. 8	3 7	10,725	Normal	0.149	0.086	24.4	2.9	0.052	Whole milk and cereal. Low total calories
222	J. E.	1 11	10,438	Normal	0.145	0.050	34.4	2.7	0.054	Mostly whole milk. Low total calories
327	R. M.	1 4	12,650	Acid	0.144	0.057	39.4	4.0	0.036	Tuberculous peritonitis. Had cod liver oil
296	E. M. 1	2 3	13,000	Constipated	0.142	0.036	25.5	3.0	0.047	
311	R. K. 2	1 11	11,290	Constipated	0.141	0.036	25.3	2.9	0.052	
313	E. K.	2 0	12,540	Normal	0.140	0.090	64.3	3.0	0.046	
369	W. R. 6	4 9	15,950	Normal	0.137	0.091	66.6	4.0	0.035	Corn oil, considerable milk curd in diet
295	M. M.	5 6	14,777	Normal	0.131	0.016	19.4	2.6	0.030	
309	H. F. 7	1 2	9,170	Constipated	0.128	0.049	38.5	4.3	0.029	
289	M. C.	6 0	14,300	Normal	0.128	0.048	37.1	3.1	0.041	
381	H. F. 8	1 3	9,425	Acid	0.124	0.075	60.7	4.6	0.026	
270	A. W. 1	4 0	14,358	Constipated	0.123	0.061	50.0	2.7	0.046	Diabetes insipidus. Large proportion carbohydrate in diet
317	K. P.	2 8	10,850	Normal	0.119	0.042	34.8	3.2	0.037	
328	D. D.	1 8	11,300	Acid	0.119	0.041	34.3	3.7	0.032	
277	R. L. 3	3 8	15,324	Normal	0.119	0.060	51.0	4.0	0.030	
300	P. B. 1	3 0	15,050	Constipated	0.117	0.059	50.2	3.2	0.053	
320	J. O. 2	2 1	13,150	Normal	0.114	0.051	44.7	2.6	0.046	
324	T. R.	4 0	15,395	Constipated	0.113	0.047	40.9	2.5	0.046	
366	W. R. 3	4 7	15,700	Normal	0.112	0.037	32.9	4.9	0.023	Corn oil, considerable milk curd in diet
367	W. R. 4	4 7	15,725	Normal	0.112	0.037	32.9	4.9	0.023	Corn oil, considerable milk curd in diet
264	F. W. 9	3 7	11,105	Normal	0.109	0.048	33.1	3.9	0.028	
372	F. W. 6	3 7	11,114	Normal	0.109	0.044	40.5	5.3	0.020	Fat-free milk, corn oil
330	H. F. 4	4 6	16,130	Normal	0.106	0.024	23.2	2.4	0.046	
373	P. V. 7	2 7	11,845	Normal	0.105	0.036	33.9	5.2	0.020	Fat-free milk, corn oil
276	W. V. 2	3 0	12,879	Normal	0.105	0.012	11.0	3.7	0.020	
287	W. W.	2 5	15,860	Normal	0.105	0.031	29.9	3.2	0.033	
369	R. L. 4	3 1	13,478	Acid	0.103	0.064	62.5	4.7	0.022	Corn oil
326	E. A. 2	7 5	13,025	Constipated	0.096	0.041	42.4	2.6	0.037	Skimmed milk, cod liver oil, rather high proportion carbohydrate
290	D. R.	3 0	14,150	Constipated	0.096	0.025	25.7	3.2	0.030	
322	M. J. 1	3 0	15,400	Constipated	0.093	0.063	68.2	3.1	0.030	
271	A. W. 2	4 1	14,755	Normal	0.092	0.046	50.0	3.3	0.028	

TABLE 2.—ABSORPTION OF CALCIUM BY HEALTHY CHILDREN TAKING A MIXED DIET, WITH AN INTAKE OF 0.09 GM. OF CALCIUM OXID PER KILO OR LESS

No.	Case	Age Yr. Mo.	Weight in Gm.	Stools	Intake of CaO Gm. per Kg.	CaO Absorbed Gm. per Kg.	Per- centage of CaO Intake Ab- sorbed	Intake of Fat Gm. per Kg.	Grams CaO Intake per Gm. Fat Intake	Remarks
297	E. M. 2	2 4	13,100	Normal	0.080	0.026	28.8	2.5	0.086	
301	F. B. 2	3 9	15,795	Acid	0.090	0.010	11.3	2.7	0.083	Corn oil
272	A. W. 3	4 1	15,334	Normal	0.089	0.050	56.5	3.4	0.026	
302	F. B. 3	3 9	15,831	Normal	0.089	0.027	29.8	2.7	0.032	
298	E. M. 3	2 6	13,744	Normal	0.088	0.028	31.4	2.5	0.036	
234	A. L. 3	0 6	12,440	Normal	0.087	—	0.0	1.8	0.050	Fever. Low calories per kilogram
299	E. M. 4	3 0	13,979	Normal	0.087	0.018	20.5	2.9	0.080	Skimmed milk, milk butter
383	E. M. 7	2 8	14,040	Normal	0.087	0.004	4.9	2.6	0.032	Fat-free milk, nut butter
274	A. W. 5	4 2	15,725	Normal	0.087	0.012	14.0	3.3	0.026	Skimmed milk, nut butter
382	E. M. 5	2 6	14,175	Normal	0.086	0.020	23.8	2.8	0.081	Fat-free milk, milk butter
254	E. M. 6	2 7	14,130	Normal	0.086	0.001	0.8	2.7	0.032	No milk except little L. A. milk. High proportion carbo-
249	E. D.	2 6	10,305	Acid	0.084	0.018	22.1	0.9	0.089	hydrate
351	R. L. 8	4 3	14,133	Normal	0.084	0.009	11.0	3.2	0.026	Skimmed milk, nut butter
349	H. J. 1	1 4	10,880	Acid	0.084	0.042	50.6	3.3	0.026	
360	R. L. 6	4 2	14,083	Normal	0.083	0.011	12.8	3.1	0.027	
354	R. L. 7	4 3	14,215	Normal	0.082	0.002	2.6	3.0	0.027	Skimmed milk, milk butter
351	F. B. 5	3 9	14,645	Normal	0.082	0.012	8.5	3.0	0.027	Skimmed milk, milk butter
355	F. B. 9	4 3	14,688	Normal	0.080	0.025	36.4	3.0	0.027	Fat-free milk, milk butter
384	F. B. 6	3 10	14,730	Normal	0.080	—	0.0	2.8	0.029	Skimmed milk, nut butter
362	F. L. 10	4 3	14,915	Normal	0.080	0.005	6.8	3.0	0.027	Fat-free milk, nut butter
385	W. B. 8	3 10	15,243	Normal	0.079	0.021	36.7	2.7	0.029	Fat-free milk, nut butter
365	W. B. 2	4 7	15,412	Acid	0.077	0.025	32.2	4.2	0.018	Corn oil
352	W. B. 5	3 9	15,060	Normal	0.076	—	0.0	2.7	0.028	Fat-free milk, milk butter
353	R. L. 5	4 2	14,115	Normal	0.071	0.031	44.0	2.6	0.025	
350	H. J. 2	1 4	10,880	Normal	0.065	0.012	18.3	2.7	0.024	
325	C. M.	5 0	13,450	Normal	0.064	0.022	33.6	2.0	0.032	Skimmed milk. High proportion carbohydrate in diet
389	E. A. 1	7 0	11,780	Acid	0.061	0.011	18.1	2.7	0.022	High proportion carbohydrate
348	M. J. 3	3 3	13,400	Normal	0.055	0.023	42.3	2.1	0.027	High proportion carbohydrate
347	M. J. 2	3 0	15,400	Acid	0.060	0.014	27.3	2.1	0.024	
337	D. K.	4 0	18,900	Acid	0.048	0.018	38.2	2.5	0.019	Very low calories per kilogram
345	E. H.	3 4	14,700	Normal	0.045	0.008	16.7	1.7	0.027	Very low calories per kilogram
336	R. K.	6 0	20,500	Acid	0.044	0.013	39.3	2.3	0.020	Very low calories per kilogram
340	L. S.	3 2	16,000	Acid	0.043	0.017	30.4	1.9	0.023	No milk, high proportion carbohydrate, much vegetable and
338	R. N.	5 10	20,200	Acid	0.018	—0.001	0.0	1.2	0.015	fruit

The relation of the absorption to the intake is summarized in Table 3. When the intake of calcium oxid exceeded 0.09 gm. per kilo, the absorption in most cases exceeded 0.03 gm. per kilo; the average was 0.055 gm. per kilo. When the intake was 0.09 gm. per kilo or less, the absorption in most cases was less than 0.03 gm.; the average was only 0.015 gm. per kilo. This absorption would hardly supply as much calcium oxid as is normally excreted in the urine by young children. It may, therefore, be inferred that an intake of less than 0.09 gm. of calcium oxid per kilo is insufficient to supply the calcium need of young children taking a mixed diet.

Relation of Calcium Absorption to Fat Intake.—With the older children who were taking a mixed diet, there was great variation in the intake of fat per kilo. On the whole, there was no close relation between the fat intake and the calcium absorption. When the fat

TABLE 3.—RELATION OF CALCIUM ABSORPTION TO CALCIUM INTAKE

Calcium Oxid Intake, Gm. per Kg.	Number of Observa- tions	Absorption 0.09 Gm. or More	Absorption 0.06 to 0.09 Gm.	Absorption 0.03 to 0.06 Gm.	Absorption Less Than 0.03 Gm.
More than 0.09 gm.	45	7	7	24	7
Less than 0.09 gm.	34	0	0	3	31
Total	79	7	7	27	38

intake was high, frequently the calcium intake also was high, and consequently there was good absorption of calcium. The intake generally included less calcium in proportion to the fat than in the case of infants who were taking modifications of cow's milk. In but few instances was there more than 0.05 gm. of calcium oxid per gm. fat in the intake, and in many there was less than 0.03 gm. The highest absorption occurred when the fat intake was greater than 3.0 gm. per kilo and when for every gram of fat in the diet there was from 0.03 to 0.05 gm. of calcium oxid, that is, when the calcium intake exceeded 0.09 gm. of calcium oxid per kilo.

Percentage Absorption of Calcium.—The percentage of the calcium intake absorbed had a very wide range, varying from 0 to 66.6 per cent. When the calcium intake exceeded 0.09 gm. of calcium oxid per kilo, the percentage absorption averaged 40.4; when the intake was 0.09 gm. or less, the average absorption was only 20.3 per cent. of the intake. The excretion of calcium oxid in the stools of healthy children taking a mixed diet did not fall below a certain minimum, whatever the calcium intake. Thus the low intake of calcium oxid did not supply much excess over the amount which was normally excreted in the stools. Hence, the amount available for absorption when the intake was low was much less than the amount which was actually found to

be absorbed when the intake was ample. This explains why, with a small intake, the percentage absorption was lower than with a larger intake, since the excretion tends to remain constant at the expense of the absorption. This observation is paralleled by a similar one in regard to fat, noted in a previous paper,¹ namely, that the percentage absorption of fat was lower when the intake was small than when it was ample.

TABLE 4.—AVERAGE ABSORPTION OF CALCIUM OXID ACCORDING TO WEIGHT

Weight in Kilograms	Number of Observations	Calcium Oxid Intake, Gm. per Kg.	Calcium Oxid Absorbed, Gm. per Kg.	Percentage of Calcium Oxid Intake Absorbed
A. When Intake Exceeded 0.09 Gm. per Kg.				
7-9.....	7	0.189	0.068	36.0
9-11.....	9	0.150	0.072	48.0
11-13.....	10	0.128	0.046	36.0
13-15.....	10	0.115	0.044	38.2
15-17.....	9	0.113	0.051	45.2
Under 11.....	16	0.167	0.070	41.9
Over 11.....	29	0.119	0.046	38.7
B. When Intake Was 0.09 Gm. per Kg. or Less				
Under 13.....	5	0.076	0.014	18.5
13-15.....	15	0.081	0.013	16.1
15-17.....	10	0.073	0.020	27.4
Over 17.....	4	0.044	0.014	31.8

TABLE 5.—AVERAGE ABSORPTION OF CALCIUM OXID ACCORDING TO TYPE OF STOOL

Type of Stool	Number of Observations	Calcium Oxid Intake, Gm. per Kg.	Calcium Oxid Absorbed, Gm. per Kg.	Percentage of Calcium Oxid Intake Absorbed
A. When Intake Exceeded 0.09 Gm. per Kg.				
Constipated.....	16	0.149	0.064	43.0
Normal.....	24	0.130	0.048	36.9
Acid.....	5	0.122	0.057	46.7
B. When Intake Was 0.09 Gm. per Kg. or Less				
Normal.....	24	0.060	0.015	18.8
Acid.....	10	0.060	0.017	28.3

Relation of Calcium Absorption to Body Weight.—The absorption of calcium oxid per kilo was to a certain extent related to the total body weight, as is shown in Table 4. With an adequate intake, that is, exceeding 0.09 gm. of calcium oxid per kilo, the children weighing less than 11 kilos absorbed, on the average, about 0.07 gm. per kilo, while those weighing more than 11 kilos absorbed, on the average, only about 0.05 gm. per kilo. The infants, considered in the preceding paper, most of whom weighed less than 7 kilos, had an average absorption of about 0.09 gm. of calcium oxid per kilo. With the children taking a mixed diet whose intake was less than 0.09 gm. per kilo the absorption showed little variation with the weight.

1. Am. J. Dis. Child. 17:423 (June) 1919.

There was no constant relation between the calcium absorption and the age, irrespective of the weight.

Relation of Calcium Absorption to Type of Stool.—The relation of the calcium absorption to the type of stool is shown in Table 5. The best average absorption was found when the stools were constipated, but the average intake for this group was the highest. Acid stools were rarely found when the intake was over 0.09 gm. per kilo. In

TABLE 6.—EXCRETION OF CALCIUM BY HEALTHY CHILDREN TAKING A MIXED DIET; (1) WITH CALCIUM IN STOOLS EXCEEDING 0.9 GM.

No.	Case	Stools	CaO Intake, Gm. Daily	Fat Intake, Gm. Daily	CaO in Stools, Gm. Daily	Fat in Stools, Gm. Daily	Fat as Soap, Gm. Daily	CaO Possibly Held as Soap, Percentage of	
								CaO in Stools	CaO Intake
295	M. M.	Normal	1.94	38.8	1.70	1.56	0.53	3.1	2.7
225	C. A. 1	Normal	1.85	35.0	1.58	4.10	2.83	17.9	15.3
296	E. M. 1	Constipated	1.84	38.8	1.37	2.29	0.66	4.8	3.6
330	H. F.	Normal	1.76	38.3	1.37	1.62	0.67	4.9	3.8
234	A. L.	Normal	1.08	21.8	1.27	1.81	0.56	4.4	5.2
384	F. B. 6	Normal	1.17	40.9	1.27	2.09	1.07	8.4	9.2
301	F. B. 2	Acid	1.42	43.4	1.26	3.53	1.06	8.4	7.5
307	H. F. 3	Constipated	1.38	36.5	1.24	2.55	1.31	10.6	9.5
313	E. K.	Normal	1.75	37.8	1.24	3.57	1.51	12.2	8.6
233	F. W. 8	Normal	1.60	31.0	1.21	4.10	2.41	19.9	15.1
276	R. L. 2	Normal	1.36	48.1	1.21	1.82	1.00	8.3	7.3
254	E. M. 6	Normal	1.21	37.7	1.20	2.94	1.55	12.9	12.8
311	R. K. 2	Constipated	1.60	31.0	1.18	4.10	1.68	5.8	4.3
352	F. B. 7	Normal	1.16	41.1	1.18	2.85	1.42	12.0	12.2
366	W. R. 3	Normal	1.76	77.0	1.18	4.66	2.26	19.2	12.9
379	H. F. 4	Normal	1.36	37.3	1.17	2.56	1.03	8.8	7.5
274	A. W. 5	Normal	1.36	52.1	1.17	2.56	1.06	9.1	7.8
287	W. W.	Normal	1.67	50.9	1.17	2.40	0.99	8.5	5.9
383	E. M. 7	Normal	1.22	38.1	1.16	2.37	1.04	9.0	8.5
289	M. C.	Normal	1.83	44.5	1.15	1.70	0.71	6.2	8.9
354	R. L. 7	Normal	1.16	43.2	1.13	3.29	1.36	11.9	11.6
327	R. M.	Acid	1.83	50.5	1.11	4.35	1.23	11.1	6.7
308	H. F. 5	Constipated	1.38	35.2	1.10	1.96	1.20	10.9	8.7
362	R. L. 10	Normal	1.18	44.6	1.10	1.68	0.79	7.2	6.7
367	W. R. 4	Normal	1.76	77.0	1.08	3.87	1.85	12.5	7.7
361	R. L. 8	Normal	1.18	45.4	1.05	1.75	0.79	7.5	6.7
324	T. R.	Constipated	1.76	38.3	1.04	1.49	0.55	5.3	3.1
360	R. L. 6	Normal	1.17	43.2	1.02	1.86	0.58	5.7	5.0
351	F. B. 5	Normal	1.20	44.4	1.02	2.74	1.46	14.3	12.1
290	D. R.	Constipated	1.36	44.8	1.01	1.26	0.38	3.8	2.8
232	J. E.	Normal	1.51	28.0	0.99	1.92	1.10	11.1	7.3
302	F. B. 3	Normal	1.41	42.5	0.99	2.25	0.75	7.6	5.3
299	E. M. 4	Normal	1.22	40.1	0.97	2.53	0.90	9.3	7.4
267	O. W. 1	Normal	1.75	37.8	0.94	1.89	1.08	11.5	6.2
380	H. F. 6	Normal	1.38	35.3	0.93	2.24	0.74	8.0	4.9
264	F. W. 9	Normal	1.21	43.6	0.93	2.92	1.45	15.6	12.0
382	E. M. 5	Normal	1.22	39.2	0.93	1.84	0.66	7.1	5.4
300	F. B. 1	Normal	1.81	34.3	0.90	2.16	1.52	16.9	8.4

the few instances when the stools were acid, the intake being adequate, the average absorption was as good as when the stools were constipated or normal. Also, when the intake of calcium oxid was less than 0.09 gm. per kilo, the absorption was practically the same whether the stools were acid or alkaline, but much lower than when the intake was adequate. That the absorption of calcium oxid was dependent more on the amount of the calcium intake than on the type of stool is shown by comparing the values for the normal groups in Table 5. With high intake, the absorption was about three times

as great as with low intake. The influence of the amount of intake of calcium oxid on both the type of stool and the absorption of calcium oxid is further illustrated by three observations on one child, M. J. (Tables 1 and 2). When the intake of calcium oxid was 0.093 gm. per kilo, the stools were constipated and the absorption was 0.058 gm. per kilo; when the intake was 0.056 gm., the stools were normal and the absorption was only 0.023 gm.; again, when the intake was 0.050 gm., the stools were acid and the absorption was only 0.014 gm.

TABLE 7.—EXCRETION OF CALCIUM BY HEALTHY CHILDREN TAKING A MIXED DIET; (2) WITH CALCIUM IN STOOLS LESS THAN 0.9 GM.

No.	Case	Stools	CaO Intake, Gm. Daily	Fat Intake, Gm. Daily	CaO in Stools, Gm. Daily	Fat in Stools, Gm. Daily	Fat as Soap, Gm. Daily	CaO Possibly Held as Soap, Percentage of	
								CaO in Stools	CaO Intake
328	D. D.	Acid	1.34	41.3	0.88	1.63	0.80	9.1	6.0
270	A. W. 1	Constipated	1.76	38.4	0.88	1.43	0.67	7.6	3.8
385	F. B. 8	Normal	1.20	41.8	0.88	1.42	0.41	4.7	3.4
305	H. F. 1	Constipated	1.69	34.9	0.87	1.68	0.90	10.3	5.3
321	F. S. 1	Constipated	2.19	61.0	0.87	2.46	1.26	14.5	5.8
317	K. P.	Normal	1.29	34.5	0.84	1.23	0.40	4.8	3.1
297	E. M. 2	Normal	1.18	32.6	0.84	1.95	0.69	8.2	5.8
312	R. K. 3	Normal	1.76	38.3	0.83	0.95	0.39	4.7	2.2
291	R. K.	Normal	1.50	42.5	0.83	2.18	1.21	14.6	8.1
298	E. M. 3	Normal	1.21	34.1	0.83	2.53	0.94	11.3	7.8
373	F. W. 7	Normal	1.21	59.4	0.80	3.01	0.44	5.5	3.6
320	J. O. 2	Constipated	1.76	38.3	0.80	1.20	0.68	8.3	3.9
365	W. R. 2	Acid	1.18	64.5	0.80	2.57	0.97	12.1	8.1
325	C. M.	Normal	1.19	36.8	0.79	1.35	0.33	4.2	2.8
277	R. L. 3	Acid	1.55	52.1	0.76	1.18	0.25	3.3	1.6
355	R. L. 9	Normal	1.18	44.6	0.75	3.34	1.08	14.4	9.6
318	D. L.	Constipated	1.45	33.6	0.73	4.04	2.64	36.2	18.2
369	W. R. 6	Normal	2.18	63.1	0.73	1.50	0.44	6.0	2.0
309	H. F. 7	Constipated	1.17	39.8	0.72	2.71	0.73	10.1	6.2
372	F. W. 6	Normal	1.21	59.4	0.72	3.03	0.66	9.2	5.5
326	E. A. 2	Constipated	1.25	34.0	0.72	4.17	2.35	32.9	18.8
364	O. W. 4	Normal	1.79	47.5	0.69	2.10	0.93	13.5	5.2
271	A. W. 2	Normal	1.36	48.1	0.68	1.21	0.50	7.4	3.7
248	E. D.	Acid	0.86	9.7	0.67	4.42	1.83	27.3	21.3
269	O. W. 5	Constipated	1.76	53.5	0.66	3.20	1.69	25.6	9.6
350	R. L. 4	Acid	1.39	63.6	0.66	3.94	1.44	21.8	10.4
268	O. W. 2	Constipated	1.76	38.5	0.65	2.16	1.40	21.5	8.0
339	E. A. 1	Acid	0.72	32.2	0.59	1.51	0.49	8.3	6.8
272	A. W. 3	Normal	1.36	52.1	0.59	2.20	0.89	15.1	6.5
350	H. J. 2	Normal	0.71	29.1	0.58	1.35	0.40	6.9	5.6
353	R. L. 5	Normal	1.00	40.0	0.56	3.57	1.93	34.5	19.3
347	M. J. 2	Acid	0.77	32.4	0.56	4.44	0.41	7.3	5.3
345	E. H.	Normal	0.66	24.5	0.55	1.06	0.55	10.0	5.3
337	D. K.	Acid	0.89	46.6	0.55	1.31	0.07	1.3	0.8
322	M. J. 1	Constipated	1.43	48.2	0.54	1.04	0.31	5.7	2.2
336	R. K.	Acid	0.89	45.6	0.54	1.62	0.21	3.9	2.4
338	R. N.	Acid	0.36	23.9	0.51	1.43	0.40	7.9	11.1
348	M. J. 3	Normal	0.85	31.3	0.49	2.06	0.40	8.2	4.7
340	L. S.	Acid	0.69	30.5	0.48	1.58	0.52	10.8	7.5
381	H. F. 8	Acid	1.17	43.7	0.46	2.07	1.07	23.2	9.1
349	H. J. 1	Acid	0.91	35.5	0.45	1.10	0.35	7.8	3.9

Tables 6 and 7 show for the cases shown in Tables 1 and 2 the calcium excretion in the stools and its relation to the total calcium intake, to the fat intake and to the excretion of total fat and of fat as soap.

Calcium Excretion and Its Relation to Calcium and Fat Intake.—Excluding two exceptionally high values, the total daily excretion of calcium oxid ranged from 0.45 to 1.37 gm., averaging 0.87 gm. Nearly

two-thirds of the values were below 1.0 gm. The excretion was but little related to the intake of calcium oxid. When the intake was low, the excretion did not fall much below the average, so that it formed a much larger proportion of the intake than when the intake was high.

There was no evidence that a very large intake of fat was followed by an excessive excretion of calcium. In fact, no relation was shown between the excretion of calcium and the intake of fat.

Relation of Calcium Excretion to Excretion of Total Fat and of Fat as Soap.—There was but little relation between the calcium excretion and the total fat excretion. Table 6, which gives the instances in which the calcium excretion was greatest, shows only a few more instances of high fat excretion than does Table 5, which gives the instances in which the calcium excretion was lowest.

In order to bring out the relation between soap excretion and calcium excretion, averages were found for the different types of stools, since the average soap excretion varies according to the type of stool. These averages are given in Table 8.

TABLE 8.—AVERAGE EXCRETION OF CALCIUM ACCORDING TO TYPE OF STOOL

Stools		Number of Observations	Intake of CaO, Gm. Daily	CaO in Stools, Gm. Daily	Fat in Stools, Gm. Daily	Fat as Soap, Gm. Daily
A:	Constipated.....	16	1.60	0.90	2.36	1.15
	Normal.....	48	1.38	0.98	2.33	1.00
	Acid.....	15	1.06	0.69	2.45	0.74
B:	Constipated.....	16	1.60	0.90	2.36	1.15
	Normal—high calcium oxid intake....	24	1.63	1.05	2.35	1.10
C:	Normal—high calcium oxid in stools...	24	1.46	1.19	2.59	1.20
	Normal—low calcium oxid in stools....	24	1.31	0.77	2.07	0.80

Table 8 A shows that in the constipated stools there was a greater soap excretion and a smaller calcium oxid excretion than in the normal stools, although when the stools were constipated, the intake was much greater. Table 8 B, which compares with the group of constipated stools a group of normal stools when the average intake was similar, brings out more clearly the contrast between these two types of stools in calcium and soap excretion.

However, excluding the constipated stools, there was a general correspondence between the variations in calcium excretion and in soap excretion. The average for the acid stools showed a much lower soap excretion, with a much lower calcium excretion, than did the normal stools, but the intake for this group was also much lower than that for the normal group. As was previously noted in the discussion of calcium absorption, the calcium intake apparently influences to a considerable extent the reaction of the stools, a low calcium intake frequently resulting in acid stools.

The relation between calcium and soap excretion is independent of the calcium intake, as is brought out in Table 8 C, in which averages are given for two groups of normal stools arranged according to the calcium excretion. With similar intake the average soap excretion in these two groups of normal stools was exactly proportional to the calcium excretion.

Both with infants fed on milk modifications and with older children taking a mixed diet there was, as has been stated, less calcium excreted in proportion to the amount of soap when the stools were constipated than when the stools were normal. This indicates that there was on the average proportionally less calcium phosphate in the constipated than in the normal stools.

The calcium lost as soap was in most cases an insignificant part of the calcium intake. In only fourteen of the seventy-nine instances in Tables 6 and 7 did it exceed 10 per cent. In the majority of the cases it was less than 10 per cent. of the total calcium excretion, and in only eight instances did it exceed 20 per cent.

EFFECT OF VEGETABLE FATS ON CALCIUM METABOLISM

In our study of fat metabolism, one group of children were given corn oil in place of milk fat, and another group nut butter in place of milk fat. The effect of these vegetable fats on calcium metabolism is shown by the averages in Table 9.

TABLE 9.—AVERAGE ABSORPTION AND EXCRETION OF CALCIUM WITH MILK FAT AND WITH VEGETABLE FAT

Kind of Fat in Diet	Number of Observations	CaO Intake, Gm. per Kg.	CaO Absorbed, Gm. per Kg.	Total CaO Intake, Gm. Daily	Total CaO in Stools, Gm. Daily	Fat as Soap in Stools, Gm. Daily
Milk butter.....	9	0.100	0.016	1.21	1.02	1.36
Nut butter.....	9	0.100	0.015	1.23	1.06	0.79
Mainly milk fat.....	35	0.119	0.047	1.52	0.95	0.97
Corn oil.....	13	0.122	0.052	1.56	0.89	1.40

In the nut butter series the children received in other respects the same diet as during the periods in which the fat given was milk fat. Hence, the findings for these two groups in Table 9 are exactly comparable. There were no control observations to be compared with the observations on corn oil. Accordingly, an average has been found for the cases given in Tables 1, 2, 6 and 7, in which the fat in the diet was mainly milk fat and the intake of calcium was comparable with that of the children taking corn oil.

Table 9 shows that the calcium absorption and the excretion were practically the same whether the fat in the diet was milk fat or vegetable fat. *The only difference in the calcium metabolism was in the*

proportion of the calcium excreted in the form of soap. With the children taking nut butter, the soap excretion was markedly lower than with milk butter and, therefore, a smaller proportion of the calcium excretion could have been bound as soap. With the children taking corn oil the soap excretion was much greater than that of the group of children with similar calcium intake who were taking mainly milk fat. The children taking corn oil received an unusually high intake of fat, so that in respect to fat excretion the two groups are not comparable.

RACHITIC CHILDREN

All the children classed here as rachitic showed, at the time of coming under observation, marked rachitic symptoms, such as inability to stand or walk, distended abdomen and typical bone changes. With most of the children observations were made before treatment was begun, as well as during the period of recovery. Table 10 gives the absorption of calcium oxid per kilo and its relation to the calcium and the fat intake.

Calcium Absorption.—The intake of calcium oxid per kilo was high, in most cases higher than that of the majority of the normal children and in no case was it less than 0.09 gm., which, with normal children, appears to be an adequate intake. In the five observations made before treatment was begun, noted in Table 8 as preliminary observations, the absorption of calcium oxid was low, mostly below the normal average. The highest absorption occurred when the intake was very high. As the condition of the children improved, the calcium absorption increased to well above the normal average, as is shown by the later observations on all the children. With two of the children later observations (371,258) made after recovery was well established, showed a subsequent decrease in absorption. These observations confirm the conclusions of other investigators that *the absorption of calcium is low when active rickets is present, increased above the normal during recovery and falls as the need for calcium ceases to be greater than normal.* It must be remembered that by calcium absorption is here meant the difference between the calcium intake and the amount lost in the stools.

The treatment in our cases consisted in a change of the diet to include more calcium and fat by increasing the milk and giving cod liver oil or milk butter, thus furnishing an extra amount of "fat-soluble A." In the latest observations on F. W. and R. M., made after recovery was well established, vegetable fat replaced butter and cod liver oil.

TABLE 10.—ABSORPTION OF CALCIUM BY RACHITIC CHILDREN TAKING MIXED DIET

No.	Case	Age Yr. Mo.	Weight in Gm.	Stools	Intake of CaO Gm. per Kg.	CaO Absorbed Gm. per Kg.	Per- centage of CaO Intake Ab- sorbed	Intake of Fat Kg.	Grams CaO Intake per Gm. Fat Intake	Remarks
235	L. H. 2	1 6	8,270	Acid	0.238	0.160	55.4	5.5	0.033	Protein milk
235	I. H. 1	2 6	6,560	Normal	0.238	0.228	84.7	8.9	0.030	Cod liver oil, high calories per kilogram
236	I. H. 2	2 8	7,045	Normal	0.248	0.189	76.4	6.7	0.037	Cod liver oil, high calories per kilogram
316	L. R. 2	1 11	8,550	Normal	0.244	0.165	67.5	6.1	0.040	Cod liver oil just discontinued
232*	F. W. 2	3 2	9,207	Normal	0.238	0.059	24.8	3.7	0.005	
315	L. R. 1	1 10	8,205	Normal	0.223	0.127	56.8	4.9	0.046	Cod liver oil just discontinued
237	R. M. 3	2 8	9,916	Normal	0.216	0.113	52.1	6.2	0.035	Butter in place of cod liver oil of previous period. Low carbohydrate
256	R. M. 2	2 7	8,570	Constipated	0.199	0.090	45.2	6.5	0.031	Cod liver oil. Low carbohydrate
261*	F. W. 1	3 1	8,900	Constipated	0.182	0.021	11.8	2.7	0.007	
263	F. W. 3	3 4	10,110	Normal	0.179	0.097	54.1	5.6	0.032	Cod liver oil
304*	R. A. 1	4 0	7,917	Acid	0.176	0.037	26.4	5.3	0.033	
253*	R. M. 1	2 5	8,017	Acid	0.163	0.026	16.1	2.4	0.007	Protein milk and whole milk. Very low calories per kilogram
258	R. M. 4	2 10	10,825	Constipated	0.151	0.068	44.7	4.3	0.035	Olive oil in place of butter of previous period
356	R. A. 2	4 3	9,515	Acid	0.150	0.084	56.3	5.4	0.028	Extra butter
357	R. A. 3	4 4	10,303	Acid	0.138	0.079	57.9	5.6	0.024	
333*	L. H. 1	1 5	8,060	Acid	0.125	0.051	40.6	4.2	0.030	Fat-free milk with corn oil
370	F. W. 4	3 6	10,700	Normal	0.113	0.080	71.1	5.6	0.020	Fat-free milk with corn oil
371	F. W. 5	3 6	10,750	Normal	0.113	0.044	38.8	5.5	0.020	

* Preliminary observation.

In the preliminary observations, the percentage of the calcium intake absorbed was with one exception much lower than normal, but during the period of improvement, the percentage absorbed was much higher than with normal children.

The intake of fat per kilo was very high, except in some of the preliminary observations, but, in general, the ratio of the calcium to the fat of the intake was similar to that of the normal children. This resulted from the increase of both fat and calcium in the diet as a therapeutic measure.

TABLE 11.—EXCRETION OF CALCIUM BY RACHITIC CHILDREN
TAKING A MIXED DIET

No.	Case	Stools	CaO Intake, Gm. Daily	Fat Intake, Gm. Daily	CaO in Stools, Gm. Daily	Fat in Stools, Gm. Daily	Fat as Soap, Gm. Daily	CaO Possibly Held as Soap, Percentage of	
								CaO in Stools	CaO Intake
262*	F. W. 2	Normal	2.18	33.8	1.64	2.40	1.79	10.9	8.2
235	L. H. 2	Acid	2.38	45.1	1.32	5.71	2.17	20.5	9.1
261*	F. W. 1	Constipated	1.62	24.2	1.43	2.97	1.82	12.8	11.2
304*	R. A. 1	Acid	1.39	42.1	1.10	3.61	2.00	18.2	14.4
253*	R. M. 1	Acid	1.31	19.6	1.10	4.24	1.84	16.7	14.0
257	R. M. 3	Normal	2.15	61.0	1.03	6.42	2.37	27.8	13.3
256	R. M. 2	Constipated	1.70	55.7	0.93	8.59	4.19	45.1	24.7
258	R. M. 4	Constipated	1.62	47.2	0.90	7.34	3.34	37.1	20.5
263	F. W. 3	Normal	1.81	56.7	0.83	3.44	2.05	24.7	11.3
315	L. R. 1	Normal	1.83	39.8	0.79	1.96	1.23	15.6	6.7
371	F. W. 5	Normal	1.21	59.4	0.74	5.30	3.00	40.6	24.8
316	L. R. 2	Normal	2.09	52.5	0.68	3.56	2.29	33.7	11.0
356	R. A. 2	Acid	1.42	51.5	0.62	2.17	0.97	15.7	6.8
357	R. A. 3	Acid	1.42	58.1	0.61	2.33	1.26	20.7	8.9
333*	L. H. 1	Acid	1.01	33.5	0.60	2.62	0.51	8.5	5.0
266	I. H. 2	Normal	1.74	46.9	0.41	1.58	0.64	15.6	3.7
370	F. W. 4	Normal	1.21	59.4	0.35	4.01	1.39	39.7	11.5
265	I. H. 1	Normal	1.76	58.3	0.27	1.49	0.94	34.8	5.3

* Preliminary observation.

Table 11 gives for the rachitic children the calcium excretion in the stools in relation to the calcium and fat intake and to the excretion of total fat and of fat as soap.

Excretion of Calcium.—The range in calcium excretion was about the same as in the case of the normal children. There was no constant relation between the calcium excretion and the intake of either calcium or fat. On the whole, the calcium excretion was not related to the fat excretion. As with normal children, the excretion of soap was sometimes parallel with that of calcium and sometimes not. The lowest values for soap excretion were found when the calcium excretion was lowest, but the highest calcium excretion was not accompanied by the highest soap. In most cases the stools of these rachitic children contained more soap but not more calcium than those of normal children, so that the calcium lost as soap was a distinctly higher proportion of both the calcium excretion and the calcium intake than was found with normal children.

Effect of Treatment.—There was great difference in the calcium metabolism between the period of active rickets and that of recovery. Accordingly, averages are given in Table 12 representing the preliminary and the later observations. Observations 258, 370 and 371 are not included in the average, because they represent periods after recovery was well established and in which the food included much vegetable fat.

TABLE 12.—EXCRETION OF CALCIUM BY CHILDREN WITH ACTIVE RICKETS AND THOSE RECOVERING FROM RICKETS

Condition of Children	No. of Observations	CaO Intake, Gm. Daily	Fat Intake, Gm. Daily	CaO in Stools, Gm. Daily	Fat in Stools, Gm. Daily	Fat as Soap, Gm. Daily	CaO as Soap, Percentage of		Percentage of CaO Intake Absorbed	Percentage of Fat Intake Absorbed
							CaO in Stools	CaO Intake		
With active rickets.	5	1.50	30.6	1.17	3.19	1.59	13.6	10.6	22.0	89.6
Recovering from rickets.....	10	1.83	57.6	0.75	3.73	1.86	24.8	10.2	59.0	93.6

The average calcium excretion was much higher during active rickets than the normal average and during recovery somewhat lower than the normal average. The average intake of calcium oxid was somewhat higher in the period of recovery, making the percentage retention much greater. Although during recovery the fat intake was nearly doubled, the excretion of total fat and of fat as soap was but slightly increased and the percentage absorption of fat as well as of calcium was much improved.

With four of the children, the extra fat was provided by the addition of cod liver oil to the diet. With one child, additional fat was given as butter, with as good result as when cod liver oil was used. Another child showed an improved absorption of calcium on a special "protein milk" in which calcium phosphate and fat were both much increased.

CHILDREN SUFFERING FROM CHRONIC INTESTINAL INDIGESTION

Table 13 presents the findings for the absorption of calcium per kilo and its relation to the calcium and the fat intake for children suffering from chronic intestinal indigestion.

Calcium Absorption.—The intake of calcium oxid per kilo was in general lower than that of the normal children, and, except in a few instances, the absorption was extremely low. There were only four values for absorption exceeding 0.04 gm. per kilo, and these occurred when the fat intake exceeded 4.0 gm. per kilo. Only once, with as high an intake of fat, was the absorption less than 0.04 gm. per kilo. A high intake of calcium did not regularly result in high absorption,

TABLE 13.—ABSORPTION OF CALCIUM BY CHILDREN SUFFERING FROM CHRONIC INTESTINAL INDIGESTION

No.	Case	Age Yr. Mo.	Weight in Gm.	Stools	Intake of CaO Gm. per Kg.	CaO Absorbed Gm. per Kg.	Per- centage of CaO Intake Ab- sorbed	Intake of Fat Gm. per Kg.	Grams CaO Intake per Gm. Fat Intake	Remarks
332	N. C. 1	6 0	8,655	Alkaline	0.242	-0.080	0.0	2.7	0.087	Skimmed milk
331	N. C. 2	6 4	8,705	Alkaline	0.241	0.003	1.4	4.3	0.056	Skimmed milk, cod liver oil
243	H. F. 1	2 10	9,890	Acid	0.202	0.015	7.5	1.7	0.116	Low fat protein milk. Very high proportion carbohydrate
249	S. M.	2 10	7,685	Acid	0.191	0.113	59.2	4.8	0.040	Diet included some L. A. milk
236	G. R. 1	5 0	12,727	Alkaline	0.158	0.032	25.6	1.0	0.158	Mostly fat-free L. A. milk. Very low calories per kilogram
294	M. H.	2 1	7,150	Acid	0.150	0.066	43.8	4.3	0.085	
334	H. L. 1	8 0	14,392	Acid	0.144	0.031	21.7	2.3	0.062	
237	G. R. 2	5 8	14,716	Alkaline	0.140	-0.026	0.0	2.5	0.068	Lactic acid milk, very little solid food
240	F. G. 2	5 5	13,060	Acid	0.133	0.051	37.7	5.7	0.023	Lactic acid milk, cod liver oil
242	F. G. 4	6 5	17,140	Alkaline	0.114	0.007	6.2	1.9	0.059	Lactic acid milk, cod liver oil. Very low calories per kilo-gram
341	A. E.	2 9	5,165	Alkaline	0.110	0.027	24.7	3.0	0.087	Very small child, very little food
244	H. F. 2	3 3	10,000	Acid	0.106	0.047	44.3	4.0	0.027	Protein milk. High proportion carbohydrate in diet
241	F. G. 3	6 0	17,000	Alkaline	0.102	0.014	13.9	3.5	0.029	Lactic acid milk, cod liver oil
255	D. R.	3 0	10,960	Acid	0.089	0.032	36.1	2.2	0.041	Skimmed milk. Very low calories per kilogram
238	G. R. 3	7 8	23,600	Acid	0.083	0.019	23.4	2.1	0.040	L. A. milk, cod liver oil. Very low calories per kilogram
323	E. R. 2	9 4	16,590	Alkaline	0.083	0.014	17.3	2.9	0.028	Cod liver oil. Low calories per kilogram
239	G. R. 4	8 0	22,850	Alkaline	0.081	0.031	37.8	2.4	0.034	L. A. milk, cod liver oil. Low calories per kilogram
278	W. R. 1	4 6	14,659	Acid	0.071	0.004	5.8	2.4	0.030	High proportion carbohydrate in diet
343	H. L. 2	8 0	14,150	Mixed w. urine	0.042	-0.014	0.0	2.1	0.020	High proportion carbohydrate in diet
335	E. R. 1	8 5	12,550	Alkaline	0.041	-0.015	0.0	2.3	0.018	Very low calories per kilogram
342	F. G. 1	5 0	10,508	Acid	0.013	0.004	28.6	2.0	0.007	No milk. Very low calories per kilogram

although in no case was there good absorption when the intake of calcium oxid was less than 0.10 gm. per kilo. The percentage of the calcium intake absorbed was, as a rule, very low.

As has been previously observed, *the absorption of calcium by infants and young children was not good unless the calcium intake bore a suitable ratio to the fat intake.* With normal children, taking a mixed diet, apparently the food should contain from 0.03 to 0.05 gm. of calcium oxid for every gram of fat, and, at the same time, the intake of both calcium and fat should be sufficient. It is seen in Table 13 that in the instances in which the calcium intake was high and the absorption poor, the ratio of calcium to fat in the intake was abnormally high. In other words, there was not enough fat in the food for the amount of calcium. In the other instances of poor absorption of calcium, the intake of both fat and calcium was too low.

TABLE 14.—EXCRETION OF CALCIUM BY CHILDREN SUFFERING FROM CHRONIC INTESTINAL INDIGESTION

No.	Case	Stools	CaO Intake, Gm. Daily	Fat Intake, Gm. Daily	CaO in Stools, Gm. Daily	Fat in Stools, Gm. Daily	Fat as Soap, Gm. Daily	CaO Possibly Held as Soap, Percentage of	
								CaO in Stools	CaO Intake
332	N. C. 1	Alkaline	2.09	23.5	2.78	3.98	1.58	5.7	7.6
237	G. R. 2	Alkaline	2.06	35.8	2.45	11.20	7.90	32.2	38.3
331	N. C. 2	Alkaline	2.10	37.6	2.07	5.99	1.83	8.7	8.7
243	H. F. 1	Acid	1.99	17.1	1.84	12.50	3.11	16.9	15.6
242	F. G. 4	Alkaline	1.95	33.0	1.83	6.19	3.50	19.1	17.9
334	H. L. 1	Acid	2.07	33.3	1.62	11.34	3.21	19.8	15.5
238	G. R. 3	Acid	1.96	49.0	1.62	7.49	4.05	26.6	20.6
241	F. G. 3	Alkaline	1.73	58.9	1.49	9.54	5.06	33.9	29.2
239	G. R. 4	Alkaline	1.85	55.1	1.15	5.11	1.92	16.7	10.5
323	E. R. 2	Alkaline	1.33	48.4	1.10	14.64	4.72	42.9	35.4
240	F. G. 2	Acid	1.73	74.2	1.06	18.67	5.66	53.3	32.7
278	W. R. 1	Acid	1.04	35.2	0.98	4.34	1.84	18.8	17.7
343	H. L. 2	Mixed w. urine	0.59	29.9	0.79	8.95			
335	E. R. 1	Alkaline	0.51	29.2	0.70	11.20	4.72	67.2	92.4
255	D. R.	Acid	0.97	23.8	0.62	4.68	2.32	37.4	23.9
294	M. H.	Acid	1.07	30.5	0.60	4.79	2.05	34.2	19.2
249	S. M.	Acid	1.47	36.7	0.60	7.30	2.67	44.5	18.2
244	H. F. 2	Acid	1.06	39.8	0.59	3.54	2.07	23.4	18.6
341	A. E.	Alkaline	0.57	15.5	0.43	1.95	1.37	31.9	24.0
342	F. G. 1	Acid	0.14	21.0	0.10	4.68	1.25	125.0	89.3

Table 14 gives for these children the calcium excretion in the stools and its relation to the calcium and the fat intake and to the excretion of total fat and of fat as soap.

Calcium Excretion.—In general, the calcium excretion was much higher than with normal children. When the excretion of calcium oxid was low, the intake was usually very low. There was no constant relation between the intake of fat and the excretion of calcium in the stools. The excretion of fat was in most cases extremely high, only once being less than 3.5 gm. The variation in the excretion of total fat and of fat as soap was entirely unrelated to the calcium excretion.

Since the excretion of soap was large, the calcium lost as soap formed a large percentage of both the calcium excretion and the calcium intake.

As the condition of chronic intestinal indigestion is characterized by the occurrence of very large stools containing a high proportion of fat, there is a temptation to withhold fat from the diet of these children. Our findings indicate that to insure a sufficient absorption of calcium, the intake of calcium must be ample and that it must be accompanied by a suitable proportion of fat. For this reason, it appears to be better to give larger amounts of fat with calcium in due proportion to children suffering from chronic intestinal indigestion, even though the loss of fat in the stools is abnormally great. As was shown previously, in our discussion of fat metabolism, these children retained a much larger amount of fat when their intake of fat was greatly increased, although their excretion of fat was at the same time increased.²

EFFECT ON CALCIUM METABOLISM OF VARIATIONS IN CALCIUM AND
FAT INTAKE

Table 15 A presents a series of observations on one child, B. W., who first came under observation suffering from osteogenesis imperfecta and malnutrition. The first observation showed with a very high calcium intake an unusually high absorption of calcium. At the time of the second observation, with about the same calcium intake, the absorption had returned to normal. The child was then given 1.6 gm. of calcium acetate daily, equivalent to 0.51 gm. calcium oxid. He received this for twelve days, including the period of observation. This salt had a bad effect on the stools, which became watery, acid and showed evidences of undigested food. The absorption of calcium oxid was unchanged; the additional calcium oxid in the intake was excreted in the stools, there being no increase in the calcium excreted in the urine. The calcium acetate was discontinued, and after the stools had become normal, there was given 2.7 gm. of tricalcium phosphate daily, equivalent to 1.46 gm. calcium oxid. He received this for eight days, including the period of observation. This salt also affected the stools unfavorably, and as in the case of calcium acetate, the excess calcium oxid was all excreted in the stools.

A few months later this child was studied again. He was then considered normal as to digestion. The first observation showed excellent absorption of calcium oxid, rather above the normal average. The fat in the food was then reduced to about one half, and the loss in fat calories was made up by increasing the carbohydrates and the protein. This made the ratio of calcium oxid to fat in the intake

2. *Am. J. Dis. Child.* **18**:107 (August) 1919.

TABLE 15.—EFFECT OF VARIATION IN CALCIUM AND FAT INTAKE

No.	Age	Weight in Gm.	Stools	Intake of CaO Gm. per Kg.	CaO Ab- sorbed Gm. per Kg.	Per- cent- age of Intake Ab- sorbed	In- take of Fat, Gm. per Kg.	Gm. CaO Intake per Gm. Fat	CaO In- take, Gm. Daily	Fat In- take, Gm. Daily	CaO in Stools, Gm. Daily	Fat in Stools, Gm. Daily	CaO Possibly Held as Soap, Percentage of		CaO in Urine, Gm. Daily	Remarks
													CaO In Stools	CaO In take		
A. Observations on B. W.																
97	1 3	5,873	Softnormal	0.231	.0117	50.8	4.7	0.048	1.36	27.6	0.67	2.54	27.6	13.3	0.021	Recovering from multiple fractures
279	1 4	6,445	Acid	0.225	0.090	40.0	6.5	0.085	1.45	41.6	0.87	4.33	29.2	17.5	0.023	Cod liver oil
403	1 5	6,649	Acid	0.319	0.095	29.7	5.7	0.056	2.12	37.7	1.49	8.06	32.2	22.6	0.017	Calcium acetate (0.51 gm. calcium oxid) given daily. Cod liver oil
404	1 5	6,590	Acid-bad	0.468	0.099	21.2	6.6	0.071	3.08	43.3	2.43					Calcium phosphate (1.46 gm. calcium oxid) given daily. Cod liver oil
280	1 9	8,950	Constipated	0.234	0.106	45.4	6.2	0.038	2.09	55.5	1.14	4.57	30.2	16.5	0.026	Cod liver oil
281	1 10	10,067	Normal	0.246	0.067	23.0	2.7	0.062	2.48	27.1	1.91	3.53	11.8	9.1	0.084	Low fat, high carbohydrate.
282	1 11	9,970	Normal	0.180	0.015	7.9	2.3	0.077	1.79	23.3	1.65	2.92	11.9	11.0	0.046	Cod liver oil
283	2 0	10,888	Constipated	0.174	0.052	30.0	3.9	0.045	1.90	42.1	1.33	3.36	14.0	9.8	0.020	Low fat, high carbohydrate. Total calories reduced. Cod liver oil
374	2 1	11,531	Normal	0.174	0.000	0.0	4.3	0.041	2.01	49.7	2.00	6.44	10.3	10.3		Proportion of fat increased. No cod liver oil
375	2 1	11,566	Normal	0.174	0.068	39.3	4.3	0.040	2.01	49.8	1.22	7.01	10.3	10.3	0.047	Fat-free milk, corn oil
377	2 2	11,735	Normal	0.244	0.139	56.8	3.8	0.064	2.87	44.5	1.24	4.65	12.7	5.5		Chalk mixture (1.0 gm. calcium oxid) daily. Fat-free milk, corn milk
378	2 3	11,777	Normal	0.243	0.166	68.3	3.8	0.064	2.87	44.5	0.91	3.30	14.8	4.7		Chalk mixture (1.0 gm. calcium oxid) daily. Fat-free milk, corn milk
B. Observations on W. R.																
367	4 7	15,735	Normal	0.111	0.043	38.6	4.9	0.023	1.76	77.0	1.08	3.87	12.5	7.7		Corn oil. Milk curd
368	4 8	15,516	Normal	0.276	0.149	54.1	3.9	0.073	4.29	60.1	1.97	4.74	13.1	6.0		Same diet, less corn oil. Chalk mixture (2.0 gm. calcium oxid) daily

abnormal. The calcium absorption was much reduced, the loss of calcium in the stools becoming much greater, although the excretion of total fat and of fat as soap was less than in the preceding period. The total food was then reduced, involving a considerable reduction in calcium intake. The absorption of calcium became very low and the excretion in the stools, although less than in the preceding period, was still abnormally high. The food was then increased to give an ample and well balanced intake of fat and calcium. The absorption of calcium rose to about the normal average for children taking a mixed diet. The excretion of calcium oxid in the stools was diminished, although still higher than the normal average. The fat in the diet was then supplied entirely in the form of corn oil, and an ample intake of both calcium and fat was provided. The first observation with this diet was made only forty-eight hours after the change. There was a negative balance of calcium and a large excretion of fat in the stools. The next observation, made a few days later, showed normal calcium absorption but no decrease in fat excretion. Later, one ounce of chalk mixture (calcium carbonate), equivalent to 1.00 gm. of calcium oxid, was given daily for six days, including the period of observation. The absorption of calcium was markedly increased, becoming much higher than the normal average; also the fat excretion was diminished. A second observation was made one week later, the chalk mixture meanwhile having been continued. The absorption of both calcium and fat was further improved. Unfortunately, urinary findings were not obtained, so that it is not known whether the extra calcium absorbed was to any extent excreted in the urine.

Table 15 A shows the effect of the administration of chalk mixture with another child, W. R. This child was given 2 ounces of chalk mixture daily, equivalent to 2.0 gm. of calcium oxid for seven days, including the period of observation. As with B. W., the calcium absorption became higher than the normal average, although in this case the excretion also was appreciably increased. More than one half of the added calcium oxid was absorbed, that is, more than was absorbed in the observation on B. W.

To summarize, the points brought out in Table 15 are as follows: High absorption of calcium oxid was found with high intake of calcium oxid; calcium absorption was not increased by administration of calcium acetate or of calcium phosphate; calcium absorption was lowered by reduction of fat intake; calcium absorption was further lowered by further reduction in fat intake and reduction in calcium intake; calcium absorption was raised by increase in fat intake to restore suitable ratio of calcium to fat; calcium absorption was only

temporarily reduced by substitution of corn oil for milk in the diet; calcium absorption was greatly increased by the administration of calcium carbonate in chalk mixture.

PROPORTION OF CALCIUM AND OF SOAP IN STOOLS OF CHILDREN
TAKING A MIXED DIET

Table 16 gives the average proportions of calcium and of soap in stools of various types from children taking a mixed diet.

TABLE 16.—AVERAGE PROPORTIONS OF CALCIUM AND OF SOAP IN STOOLS OF CHILDREN TAKING A MIXED DIET

Condition of Children	Stools	Num- ber of Observa- tions	CaO Intake, Gm. Daily	CaO Per- centage of Total Solids	CaO Per- centage of Total Salts	Fat as Soap, Percent- age of Total Solids
Normal.....	Constipated	23	1.62	8.3	41.8	10.1
Normal.....	Normal	45	1.38	7.7	39.1	7.9
Normal—high calcium oxid intake..	Normal	21	1.66	9.0	42.4	9.2
Normal—low calcium oxid intake..	Normal	24	1.13	6.3	36.3	6.5
Normal.....	Acid	18	1.10	5.1	33.0	5.9*
Normal—high fat diet, much corn oil.....	Normal	13	1.61	6.0	38.1	9.4
Normal—high fat diet, much corn oil.....	Acid	4	1.48	4.9	31.7	6.7*
Rachitic.....	Normal and constipated	10	1.85	7.7	35.9	17.4
Rachitic.....	Acid	6	1.49	6.1	39.3	10.4*
With chronic intestinal indigestion	Alkaline	10	1.62	8.6	38.6	18.2
With chronic intestinal indigestion	Acid	9	1.48	4.6	34.8	14.0*
Normal—no milk in diet.....	Acid	1	0.36	1.5	15.4	1.2*
With chronic intestinal indiges- tion—no milk in diet.....	Acid	1	0.14	0.6	3.7	7.9*

* Value probably too high since stools were acid.

The calcium percentage of total solids of the stools of children taking a mixed diet was considerably lower than that of the stools similar in water content of infants taking modifications of cow's milk. This is explainable by the presence of food waste, such as cellulose, in the stools of children taking a mixed diet. The constipated stools had a somewhat higher percentage of calcium than the average of all the normal stools. This was related to the calcium intake, as was shown by dividing the normal stools into two groups. The first of these corresponded to an average intake similar to that for the group of constipated stools, and showed an average value for calcium percentage of total solids even higher than that of the constipated stools. The acid stools contained a smaller proportion of calcium oxid than did the normal. Acid stools occurred more frequently when the intake of calcium was low, but difference in intake did not entirely account for the smaller proportion of calcium. This is shown by comparing the average for the group of normal stools corresponding to a low intake with the average for the acid stools. The calcium percentage of total solids was somewhat lower in the acid stools than in the normal

stools corresponding to the same intake. When the intake included large amounts of corn oil the calcium percentage of total solids of the stools was appreciably lower than when milk fat was taken. The total solids of these stools were increased by the large excretion of fat, while the calcium was not increased in proportion.

The normal stools of rachitic children contained a lower proportion of calcium than did those of normal children. With these children also the total solids of the stools were increased by high fat excretion. The acid stools of rachitic children showed a rather high percentage of calcium than the acid stools of normal children, but the intake of calcium was higher with the rachitic children.

The stools of children suffering from chronic intestinal indigestion had a lower percentage of calcium than those of normal children when the intake was similar. The lower percentage of calcium in the stools of these children, also, was due to a much increased proportion of fat.

The stools of two children who had no milk in the food and consequently a very small calcium intake showed a calcium percentage of solids in the stools far below the usual.

With mixed diet the calcium formed a smaller percentage of the total salts than with milk modifications, and the variations corresponded, in general, with the variations in calcium percentage of total solids.

With mixed diet the average soap percentage of total solids was always low and varied with the calcium percentage of total solids. With children taking large amounts of corn oil the soap percentage of total solids was proportionally higher than the calcium percentage. With the abnormal children the soap percentage was markedly higher than with normal children having the same type of stool, while the calcium percentage showed less difference from the normal.

With mixed diet the variations in calcium percentage of total solids of the stools was not related to the water content, since the stools varied little in this respect. Normally, the two factors which mainly affected the calcium percentage of total solids were the calcium intake and the reaction of the stools.

The following summary gives answers based on our observations to the questions on calcium metabolism stated in the preceding paper.

SUMMARY

1. *Normal Absorption and Excretion of Calcium.*—With children taking a mixed diet, the absorption of calcium per kilo was lower than that of infants taking modifications of cow's milk, averaging, when the intake was adequate, 0.055 gm. of calcium oxid per kilo.

The average daily excretion of calcium oxid in the stools of children taking a mixed diet was 0.87 gm.

2. *Calcium Absorption and Excretion in Relation to Calcium and Fat Intake.*—With children taking a mixed diet, the intake of calcium oxid per kilo was lower than that of the infants, the average found for seventy-nine cases being 0.108 gm. per kilo. The absorption of calcium oxid when the intake of calcium oxid was more than 0.09 gm. per kilo in nearly every case exceeded 0.03 gm. per kilo, with an average of 0.055 gm. When the intake was only 0.09 gm. per kilo or less, the absorption rarely exceeded 0.03 gm. per kilo, and in several instances there was negative balance; the average was only 0.015 gm.

The percentage of the calcium intake absorbed when the intake exceeded 0.09 gm. per kilo averaged 40.4; when the intake was 0.09 gm. or less, the absorption averaged only 20.3 per cent.

It may, therefore, be inferred that an intake of at least 0.09 gm. of calcium oxid per kilo is necessary to insure a good absorption by children taking a mixed diet.

The best absorption of calcium oxid occurred when the intake of fat exceeded 3.0 gm. per kilo, and when, at the same time, for every gram of fat there was in the diet from 0.03 to 0.05 gm. of calcium oxid. This is a somewhat lower proportion of calcium oxid to fat than was needed to insure good absorption of calcium oxid by infants taking modifications of cow's milk.

When calcium in the form of chalk mixture (calcium carbonate) was added to the diet, there was a greatly increased absorption of calcium. When calcium was added as calcium acetate or as calcium phosphate the absorption was not increased.

The excretion of calcium was not so closely related to the intake of calcium as in the case of infants taking modifications of cow's milk, and was not at all related to the fat intake.

3. *Effect of Very Small Calcium Intake.*—A very small intake of calcium resulted in either an absorption not much greater than the amount normally excreted in the urine or in a negative balance of calcium.

4. *Relation of Age and Weight to Calcium Absorption.*—The average absorption of calcium oxid per kilo was somewhat lower with the larger children, but the age, irrespective of the weight, had no constant relation to the calcium absorption.

5. *Relation Between Excretion of Calcium and Excretion of Total Fat and of Fat as Soap.*—The excretion of calcium in the stools was not at all related to the excretion of total fat, but bore some relation to the excretion of fat as soap. However, in the constipated stools, which contained the most soap, the calcium excretion was not so great as in the normal stools when the intake of calcium oxid was the same.

6. *Loss of Calcium in Soapy Stools.*—The calcium lost as soap in the stools of normal children taking a mixed diet was, in most cases, an insignificant part of the calcium intake.

7. *Calcium Percentage of Total Solids of the Stools.*—The calcium formed a smaller proportion of the total solids of the stools of children taking a mixed diet than of the stools of infants taking modifications of cow's milk. The calcium percentage of total solids was lower in acid than in normal or constipated stools. The two factors chiefly affecting the percentage of calcium in the stools of children taking a mixed diet were the amount of calcium intake and the reaction of the stools. The soap percentage of total solids followed on the average the variation in the calcium percentage of total solids.

8. *Calcium Absorption and Excretion in (a) Chronic Intestinal Indigestion; (b) Active Rickets; (c) Recovery from Rickets.*—The absorption of calcium by children with chronic intestinal indigestion was extremely low. In the only instances in which the absorption was near the normal both calcium and fat intake were high. The excretion of calcium in the stools was very high, except when the intake was unusually low. The excretion of total fat and of fat as soap was very high, but was not paralleled by the calcium excretion.

The calcium absorption of children with active rickets was lower than that of normal children, even though the calcium intake was ample. The calcium excretion in the stools was somewhat higher than the average excretion in the stools of normal children.

During recovery from rickets, the absorption of calcium was higher than the average for normal children. This improvement accompanied the taking of cod liver oil or additional butter with a diet containing an ample amount of calcium. The calcium excretion in the stools of children recovering from rickets was lower than that in the stools of normal children.

9. *Effect on Calcium Metabolism of (a) Cod Liver Oil; (b) Vegetable Fats.*—Cod liver oil increased the absorption of calcium, except in cases in which the intake of calcium or of fat was very low.

The substitution of vegetable fats for milk fat did not affect the calcium metabolism of children taking a mixed diet.