CIV. THE MINERAL CONTENT OF HUMAN MILK IN NORMAL AND RACHITIC FAMILIES.

By STEPHEN VEITCH TELFER.

*Medical Department, Royal Hospital for Sick Children, and Institute of
Physiology, University of Glasgow.*

(Received June 13th, 1924.)

THE importance of an adequate supply of mineral matter in the diet to ensure normal growth and nutrition was demonstrated by experimental methods many years ago. The earliest workers observed that an insufficiency of minerals in the food of young animals invariably gave rise to defective calcification of the bones, and often to progressive malnutrition resulting in death. The exact nature of the pathological changes which follow an insufficient utilisation of one or other of the essential inorganic elements is still far from being understood.

The more recent work in experimental rickets has emphasised the importance, not only of the actual amount of the mineral matter of the diet, but also of the proportions of the individual salt constituents independently of any other factor. The metabolism of lime and of phosphoric acid has naturally received most attention in investigations of this nature.

In view of the fact that the rachitic changes in the bones of infants become manifest during the first year of life and can be detected often in the early months, the mineral content of human milk has, in the past, been subjected to critical examination in relation to the cause of rickets. Korenchevsky [1922] has collected and examined the data of earlier workers on this subject, and has discussed calcium starvation as a possibly important aetiological factor in the disease. According to the results of Bahrtdt and Edelstein, Schabad, and other continental workers quoted by him, the milk of mothers of rachitic children is often subnormal in calcium content.

A number of specimens of human milk obtained from women of the poorer classes living in the industrial districts of Glasgow were examined to ascertain whether any definite deficiency of calcium or phosphorus was invariably associated with the onset of rickets. The milk on which infants developed rickets was compared with other specimens on which the infants remained free of the disease. In addition, a number of milks were selected for examination from women with healthy children living in country villages (Fifeshire and Renfrewshire).

METHODS.

The milk samples were obtained by exhausting the breast artificially. In each case the maximum quantity was collected to lessen the risk of lack of uniformity in sampling, since the fat content of milk is considerably higher in the last portion withdrawn from the breast. Where it was found impossible to withdraw sufficient milk for analysis, specimens were collected from the same subject daily over a period of three or four days and mixed.

A series of estimations was carried out on specimens of milk collected in three successive and approximately equal quantities of 40 cc. in a number of different cases. These results (Table I) show that there was practically no variation in the mineral content with the degree of breast exhaustion. The increase of fat concentration was much less than that which has been observed in animal milks.

The estimations of fat, total solids, ash, lime and phosphoric acid were made by the usual methods (Table II).

Table I. *Examination of human milks collected in three successive portions of 40 cc.*

No.	Fat %			Total solids %			Ash %			CaO %		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
1.	2.84	4.97	5.28	—	—	—	—	—	—	—	—	—
2.	2.32	4.03	6.19	—	—	—	—	—	—	—	—	—
3.	4.36	5.77	7.20	14.09	15.66	16.23	0.19	0.17	0.18	—	—	—
4.	0.4	1.33	1.96	10.43	11.30	11.58	0.21	0.24	0.20	—	—	—
5.	1.12	1.4	1.48	10.75	11.24	11.54	0.23	0.25	0.21	—	—	—
6.	3.4	4.0	5.3	12.41	13.2	14.7	0.23	0.22	0.24	0.055	0.053	0.053
7.	2.17	2.93	3.31	11.48	12.65	12.77	0.18	0.20	0.19	0.033	0.031	0.031
8.	1.19	2.58	3.12	10.72	12.02	13.38	0.17	0.17	0.16	0.033	0.032	0.033

Table II. *Mineral content of human milk in rachitic and non-rachitic families (Industrial Class—Town Dwellers).*

Group A. Non-rachitic.

No.	Age of mother (years)	Period of lactation	No. of children	%			
				Fat	Ash	CaO	P ₂ O ₅
1.	20	3 weeks	2	1.58	0.18	0.048	0.038
2.	25	4 "	1	3.16	0.24	0.04	0.036
3.	—	5 "	1	1.74	0.18	0.04	0.04
4.	35	7 "	5	2.68	0.20	0.044	0.033
5.	29	3 months	4	0.6	0.17	0.05	0.036
6.	23	4 "	2	2.79	0.20	0.055	0.048
7.	27	4 "	1	2.34	0.23	0.05	0.03
8.	20	6 "	3	1.96	0.23	0.06	0.05
9.	25	6 "	2	1.72	0.21	0.045	0.039
10.	36	6 "	2	3.28	0.15	0.044	—
11.	25	7 "	3	1.8	0.20	0.04	0.04
12.	24	13 "	3	3.23	0.16	0.048	0.04
Average				2.24	0.196	0.047	0.04

Group B. Rachitic.

No.	Age of mother (years)	Period of lactation	No. of children	%			
				Fat	Ash	CaO	P ₂ O ₅
1.	36	3 weeks	4	2.08	0.24	0.048	0.035
2.	28	5 "	5	3.21	—	0.06	0.06
3.	20	2 months	1	3.74	0.16	0.04	0.04
4.	27	2 "	3	2.35	0.19	0.05	0.05
5.	39	3 "	8	0.3	0.16	0.04	0.03
6.	30	3 "	4	2.51	0.20	0.05	0.032
7.	42	3 "	11	5.15	—	0.05	0.04
8.	28	4 "	5	1.6	0.22	0.048	0.023
9.	31	4 "	6	3.61	0.17	0.05	0.045
10.	29	4 "	9	3.53	—	0.05	—
11.	30	7 "	5	3.59	0.25	0.056	0.045
12.	23	8 "	2	3.91	—	0.04	0.036
13.	27	1 year	3	0.92	—	0.05	0.05
14.	30	1 "	3	2.33	0.20	0.044	0.024
15.	32	1 "	4	3.99	0.16	0.034	0.037
Average				2.85	0.195	0.047	0.039

Group C. Milk of Women living in Country Villages

No.	Age of mother (years)	Period of lactation	No. of children	%			
				Fat	Ash	CaO	P ₂ O ₅
1.	44	5 days	10	2.07	0.22	0.035	0.05
2.	24	10 "	2	3.19	0.17	0.045	0.045
3.	36	10 "	2	2.3	0.17	0.033	0.05
4.	18	12 "	1	4.32	0.23	0.054	0.056
5.	27	12 "	3	2.8	0.19	0.032	0.039
6.	24	17 "	2	2.2	0.20	0.04	0.046
7.	25	4 weeks	2	3.66	0.18	0.035	0.037
8.	26	5 "	3	4.02	0.23	0.04	0.04
9.	34	6 "	11	3.67	0.17	0.049	0.05
10.	43	2 months	11	2.15	—	0.05	0.04
11.	27	3 "	3	5.03	—	0.042	0.035
12.	23	6 "	1	2.66	0.20	0.047	0.043
Average				3.17	0.196	0.042	0.044

RESULTS.

No appreciable differences in the mineral content of the milks of the non-rachitic and rachitic groups were observed, the average figures obtained being nearly identical. In both groups there is a considerable range of variation of lime, phosphoric acid and fat, but in each series the CaO of most of the specimens lies within the limits 0.04–0.05 %. In the rachitic group only one specimen was below 0.04 %. Several milks in both groups contained appreciably less phosphoric acid than lime. These were probably abnormal in this respect, since a slight excess of phosphoric acid over the calcium equivalent necessary for bone formation is required for the growth of the soft tissues. That this excess is normally supplied in milk is shown by the following examples, taken from the compilation on phosphorus metabolism by Forbes and Keith [1914].

	Cow	Sheep	Goat	Pig	Dog	Mare
CaO %	0.168	0.245	0.197	0.257	0.44	0.123
P ₂ O ₅ %	0.215	0.292	0.284	0.317	0.48	0.130
Author	Sherman	Abderhalden			Bunge	

A number of specimens in both groups were very deficient in fat, a feature not uncommon in the milk of women among the poorer industrial classes. In a study of the calorific value of human milk in relation to marasmus made by the late Major H. S. Hutchison, several of the specimens obtained from women attending a children's dispensary were almost transparent.

In Group C, the lime content is very slightly less than in the preceding groups, four of the specimens containing less than 0.04 % CaO, but the phosphoric acid content is distinctly higher than the lime. The milks of the women living in the country were therefore relatively richer in phosphorus than those of women living under poor conditions in the town.

Korenchevsky [1922] has drawn attention to an observation of Pfeiffer on the ash of human milk, that the percentage of phosphoric acid of the total ash is subnormal in the milk of mothers of rachitic children. This observation is based on the results obtained from the examination of only three "rachitic" milks, and in one of these the percentage of phosphoric acid quoted (24.99 %) is higher than the normal average (24.7 %) determined by Pfeiffer.

In Groups A and B, the ash contained 20 % of phosphoric acid, and the latter was equal to or less than the lime in all the specimens. In Group C, 22.4 % of phosphoric acid was present in the ash, while, with two exceptions, it was equal to or greater than the lime. No milks abnormally poor in fat were obtained from country sources. One milk was extremely high in mineral content. Three specimens collected on different days gave the following results:

Fat	Ash	CaO	P ₂ O ₅
4.52	0.41	0.096	0.089
3.96	—	0.084	0.076
4.06	0.33	0.088	0.076

De Buys and Von Meysenbug [1924] have recently published the results of calcium determinations in a large series of breast milks. In 55 cases in which the babies developed rickets, they found the calcium percentages varying from 18.4 mg. (0.025 % CaO) to 39.6 mg. (0.055 % CaO). The average for 19 normal milks was 32.6 mg. (0.045 % CaO). In some of the most severe cases of rickets the calcium content of the milk was well within the normal range. On the other hand, very low extremes in the calcium content of the rachitic group were recorded as compared with the normal series. These observers corroborate the findings of Burhaus and Smith [1923], that the average calcium content of the milk in white races (30.79 mg. Ca %) is higher than that of coloured women (25.41 mg. Ca %), an interesting observation in view of the fact that rickets is more prone to develop in negro children.

The results presented here confirm the conclusions of Schabad [1911] that infantile rickets can occur when the calcium content of the breast milk is normal or even above normal, so that a deficiency of calcium in the milk cannot be the only cause of rickets.

I am indebted to Prof. D. Noël Paton for helpful advice and criticism in this work, the expenses of which were defrayed by a grant from the Medical Research Council.

SUMMARY.

1. The mineral content of 27 specimens of breast milk of women living under poor conditions in the industrial quarters of Glasgow was determined.

2. No appreciable differences were found in the composition of the milks, whether the infants developed rickets or did not. The fat content of several specimens of both groups was abnormally low.

3. Twelve specimens of milk from healthy women living in country villages were examined for purposes of comparison. In these the ratio of phosphoric acid to lime was slightly higher than in the milk of women living in a poor environment.

4. Schabad's conclusion that infantile rickets may develop on breast milk with a high calcium content is confirmed.

REFERENCES.

- Burhaus and Smith (1923). *Amer. J. Dis. Child.* **26**, 303.
De Buys and Von Meysenbug (1924). *Amer. J. Dis. Child.* **27**, 438.
Forbes and Keith (1914). *Ohio Agric. Exp. Station Bull.* No. 5. Technical Series.
Korenchevsky (1922). *Med. Res. Council Spec. Rep. Series*, No. 71.
Schabad (1911). *Jahrb. Kinderheilk.* **74**, 511.