III. THE CALCIUM REQUIREMENT OF OLDER MALE SUBJECTS

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(Received 9 November 1938)

It is now generally accepted that Ca is an important essential in nutrition. It is believed, moreover, that, in most countries of the world, large sections of the population would be more adequately nourished were they to ingest more Ca. This applies to Great Britain [Orr, 1937], India [McCarrison, 1932-3], U.S.A. [Sherman, 1920, 2], China [Kung & Yeh, 1937; Liu *et al.* 1937], and figures given by Rubner [1920] leave little doubt that it applies also both to Germany and to Japan.

Orr & Clark [1930] showed that the health of school children could be improved and that their growth could be accelerated by giving them a supplement of whole or separated milk. More recent experiments by Gaunt *et al.* [1938] indicated that the benefits resulting from the addition of milk and greenstuffs to poor-class diets were due mainly to the Ca and P which these additional foodstuffs contain. Aykroyd & Krishnan [1938] have found the health and growth rates of Indian school children to be improved by a daily ration of Ca lactate.

The food shortage in Germany and Austria during the world war showed very clearly the result of a widespread lack of Ca and P. Hundreds of cases of "hunger osteomalacia" occurred. Alwens [1919], after careful clinical investigation of 29 such cases, mostly old subjects, in Frankfurt, concluded that they were suffering from osteoporosis due to protein, Ca and P deficiency. Dalyell & Chick [1921] investigated over 100 cases and also thought "hunger osteomalacia" to be a nutritional disease of the skeleton. Hume & Nirenstein [1921] showed that the incidence of the disease was highest in winter when the diet was poorest and that there was a remarkable increase of incidence with age. Of 131 subjects examined 115 were over 40 years of age and one-third were between 60 and 70.

Such observations show the importance of the hypothesis of Meulengracht & Meyer [1936] who, after intensive investigation of 5 cases of senile osteoporosis, came to the conclusion that long-standing Ca deficiency was the main factor in the genesis of this disease. Meulengracht [1938] has again advanced this hypothesis in connexion with a case of senile osteoporosis produced by repeated purgation with Na_2SO_4 . Leitch [1936-7] supports Meulengracht's opinion as to the relation of Ca deficiency to senile osteoporosis.

Before the effects of a long-standing deficiency of Ca can be properly evaluated it is necessary to ascertain the Ca requirement of older subjects. A decrease of requirement with age would offset, to some extent, the effects of low intake. It is also of importance to find out whether, after depletion of these elements, the older organism will store additional Ca and P in the same way as the young adult. The following balance experiments were therefore undertaken to decide these points.

PLAN OF EXPERIMENTS

The experiments were all done in the metabolic ward of the Aberdeen Royal Infirmary. Balances were determined on 10 subjects, mostly old or middle-aged. A preliminary period on a low Ca diet was followed by one on a higher intake. A specially trained sister supervised the preparation and consumption of the diets and the collection of all excreta.

In all cases balances were determined every 3 days but the data for the first 3 days on the low Ca diet were not included in the results. Both low and high Ca periods lasted at least 9 days.

Duplicate diets were analysed for total Ca and P in 3-day lots; urine and faeces were similarly analysed every 3 days. The methods of analysis were, with minor modifications, those recommended in *Technical Communication* No. 9 of the Imperial Bureau of Animal Nutrition [Godden, 1937], i.e. P was estimated by the method of Fiske & Subbarow [1925], and Ca by the method of McCrudden [1909; 1911]. Ca in urine was determined by direct precipitation. The urine was, if necessary, deproteinized prior to precipitation, acetic acid being used for the purpose. Ca in ashed diet and in ashed faeces was determined by precipitation of the oxalate in the presence of sodium acetate. Dry ashings preceded all P determinations; in the case of diet and faeces, $\text{Mg}(\text{NO}_3)_2$ was added and with urine Ca acetate was employed. All ashings were completed in an electric muffle.

Male outpatients from the diabetes and obesity clinic of Dr A. Lyall were used; they varied in age from 32 to 70 and were kept in bed during the whole period of the experiment. Blood Ca and P, and serum phosphatase of all patients were within normal limits.

The dietary history of these patients for the previous 6 months was known, including their Ca and P intakes. The composition of the diet during the preliminary low Ca period was adjusted to a similar level. The diets used in the balance experiments consisted entirely of normal foodstuffs and the Ca and P contents in the second period were raised solely by addition of foods rich in these materials. In cooking the food, distilled water was used and all such water was included in the diet, for example in soups. Eggs were fed always without shells since some patients were found to eat egg-shells. Only on very few occasions did patients reject food; in all such cases a similar rejection was made from the duplicate diets. The composition of the two diets is given in Table I.

Table I. *Composition of diets I and II expressed as daily intakes*

	Diet I	Diet II
Calories	1493	1509
Protein	59	85
Carbohydrate	141	146
Fat	77	65
Ca	0.53	0.88
P	0.85	1.23
Ca/P ratio	0.62	0.72
Ca as % of dry wt. of diet	0.184	0.273
P as % of dry wt. of diet	0.294	0.381

RESULTS

All the data relevant to the Ca and P retentions of the subjects investigated will be found in Table II. On the lower Ca level it will be seen that four of the subjects were in positive Ca balance and five in negative, while the remaining one

Table II. *Summary of balance experiment results*

Subject no.	Age of subject	No. of 3-day balances	Ca (mg. per day)					Balance
			Intake	Output				
				Urine	Faeces	Total		
1	53	7	510	130	383	513	- 3	
		1	819	157	532	689	+ 130	
2	45	5	491	141	370	511	- 20	
		4	861	206	539	745	+ 116	
3	66	3	503	192	382	574	- 71	
		3	869	195	605	800	+ 69	
4	53	3	503	199	251	450	+ 53	
		3	869	266.5	463.5	730	+ 140	
5	42	3	510	156	531	687	- 177	
		3	942	201	472	673	+ 269	
6	32	3	510	165	370	535	- 25	
		3	942	214	544	758	+ 184	
7	69	3	567	77	450	527	+ 40	
		3	896	100	505	605	+ 291	
8	65	3	567	65	281	346	+ 221	
		3	896	104	595	699	+ 197	
9	65	3	544	49	407	456	+ 88	
		3	849	77	660	737	+ 112	
10	40	3	544	542	136	678	- 134	
		3	849	544	293	837	+ 12	
Average of the 10 subjects			524	172	356	528	- 4	
			879	206	521	727	+ 152	

Subject no.	Age of subject	No. of 3-day balances	P (mg. per day)					Balance
			Intake	Output				
				Urine	Faeces	Total		
1	53	7	879	832	200	1032	- 153	
		1	1210	960	256	1216	- 6	
2	45	5	851	814	214	1028	- 177	
		4	1286	987.5	283.5	1271	+ 15	
3	66	3	839	746	245	991	- 153	
		3	1201	807	365	1172	+ 29	
4	53	3	839	836	135	971	- 132	
		3	1201	1083	238	1321	- 121	
5	42	3	840	833	242	1075	- 235	
		3	1226	964	237	1201	+ 25	
6	32	3	840	760	208	968	- 128	
		3	1226	962	277	1239	- 13	
7	69	3	845	737.5	229.5	967	- 122	
		3	1311	883	249	1132	+ 179	
8	65	3	845	630	193	823	+ 22	
		3	1311	664	428	1092	+ 219	
9	65	3	858	699	227	926	- 68	
		3	1149	691	428	1119	+ 30	
10	40	3	858	1015	125	1140	- 282	
		3	1149	977	210	1187	- 38	
Average of the 10 subjects			849	790	202	992	- 147	
			1227	898	297	1195	+ 32	

was in equilibrium. The average intake of the whole group while on the lower Ca diet was 524 mg. Ca per day, and the average output was 528 mg. per day, i.e. the subjects as a group were practically in equilibrium.

The P balances on the lower Ca diet were negative in every case except no. 8. The average P intake was 849 mg. and the average output 992 mg. per day.

At the higher Ca level all the subjects without exception went into positive balance. The average Ca intake of the group was 879 mg. per day and the average output 727 mg. per day. In all but one case 900 mg. Ca per day would certainly more than suffice to keep these subjects in Ca equilibrium. The time necessary to attain equilibrium at the higher level of intake is evidently considerably longer than the duration of the present experiments.

On the higher Ca intake the P intake was also higher and the average P balance of the group was positive. The average P intake was 1227 mg. per day and the average output 1195 mg. per day. Individually the subjects were all very nearly in equilibrium except no. 4 who was in a distinct negative balance and nos. 7 and 8 who were in strongly positive balance. At the higher level of P intake no. 4 was still losing P despite his having been in no way unusual at the lower level. At both levels of intake he was retaining Ca.

All the subjects excreted P chiefly in the urine at both intake levels, while Ca was excreted chiefly in the faeces. No. 10 was unusual in excreting much more Ca in the urine than in the faeces. On the lower Ca diet his output in the urine alone almost exactly equalled the total Ca ingested. This abnormality suggested further investigation which is now being carried out.

DISCUSSION

The figure here obtained for the Ca requirement of older men agrees well with the estimate of 450 mg. per person per day given by Sherman [1920, 1]. It also agrees well with that of Leitch [1936-37] for adult, non-pregnant, non-lactating women; she found a requirement of 550 mg. per day. Brull [1936], from subjects who were in negative balance, arrived at a similar estimate, though it is doubtful if the output of a subject in negative balance is a true index of his requirement. The data of Kelly & Henderson [1929-30] seem to indicate retention at a level considerably lower than the one here found. As their subjects were negro prisoners in Africa these better retentions may have indicated that the skeletons of their subjects were partly depleted of Ca and P before coming under investigation, since Rottensten [1938] has shown that retention may be more efficient in such circumstances. The subjects had been subsisting for some time on the prison diet containing 300 mg. Ca and 2390 mg. P per day.

The P requirement of the older adults here considered is approximately 1200 mg. per day. This figure exceeds the estimate of 900 mg. given by Sherman [1920, 1]. Requirements of this order have, however, frequently been reported, as shown in the review of P metabolism by Forbes & Keith [1914]. Figures quoted by Orr & Clark [1930] are also of this order.

Both diets were of normal composition and it is of interest that the Ca/P ratio was so low in each case. This is, however, apparently usual in human dietaries since many diets determined by survey at the Rowett Research Institute have similarly low ratios. Little can be argued from the ratio in the present experiments since it is virtually the same in both diets.

It may appear strange that subjects who were apparently in equilibrium on the lower intake should have gone into marked positive balance when the intake was increased. This is almost certainly due to the fact that the lower level

represents the lowest for maintenance and allows no margin against unforeseen Ca loss. It had been noted that at this level an attack of diarrhoea might cause a considerable loss of Ca. A study of Table II shows that at the lower level there were as many negative as positive balances, while at the higher level they were all positive. This increase in or change to a positive balance probably represents the making good of small losses of Ca incurred over a considerable prior period.

The Ca requirements of older males are much the same as those of younger adults: the effect, therefore, of long subjection to a diet low in Ca is not offset by increasing age. The older organism likewise resembles the young adult in that it readily retains Ca and P after depletion. The possible bearing of these facts on the genesis of senile osteoporosis has been discussed in the introduction.

SUMMARY

Ca and P balances determined on 10 older males are reported, and the possible bearing of the results on the aetiology of senile osteoporosis is discussed. The results indicate that Ca and P equilibrium may be attained with 520 mg. Ca and 1200 mg. P per day.

The writer is indebted to Dr A. Lyall, Clinical Chemist to the Aberdeen Royal Infirmary, for providing the clinical material, for supervising the management of the patients and for much advice; to Sister Stephen for her help in the accurate preparation of the diets and careful collection of the excreta; and to Dr J. T. Irving, Head of the Physiology Department of the Rowett Research Institute, for his help and criticism. This work was made possible by a whole-time grant from the Medical Research Council for which grateful acknowledgment is made.

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