OPTIMUM CALCIUM REQUIREMENT

BY

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The serum of a normal adult is generally considered to contain 9 to 11.5 mg. of calcium per 100 c.cm. Table I gives the calcium determinations of 51 cases taken at random. The blood was examined soon after admission to the Liverpool Heart Hospital. We had no knowledge of the diet calcium of these patients. It will be seen that only in 4 cases out of 51 was the serum calcium below 9 mg.

TABLE I.—Serum Calcium

No.	Serum Ca mg./100 c.cm.	No.	Serum Ca mg./100 c.cm.	No.	Serum Ca mg./100 c.cm.	No.	Serum Ca mg./100 c.cm.	No.	Serum Ca mg./100 c.cm.
1	10.1	11	9.2	21	9.0	31	10.0	41	9.7
2	10.3	12	8.4	22	9.3	32	11.7	42	11.2
3	9.4	13	9.0	23	10.4	33	10.5	43	10.1
4	10.4	14	9.1	24	11.6	34	11.0	44	10.4
5	10.1	15	8.4	25	10.2	35	9.8	45	10.6
6	10.0	16	9.6	26	9.5	36	10.1	46	11.5
7	12.0	17	9.8	27	10.4	37	11.7	47	11.3
8	12.9	18	10.5	28	9.5	38	10.8	48	11.9
9	11.6	19	9.1	29	10.5	39	11.0	49	10.9
10	8.0	20	8.4	30	9.2	40	11.0	50	12.0
								51	10.4

The question arises how far calcium intake in diet influences serum calcium. In one patient who was kept for fourteen days on a diet containing 1.6 grammes of calcium daily the serum calcium rose from 12.9 to 13.6 mg. and fell below 10 mg. when the calcium intake was reduced to 0.7 gramme a day. But such results are by no means constant. In a good many of our cases a low calcium intake did not lower the level of serum calcium appreciably; for instance, in one patient having a calcium intake of 2 grammes daily for two weeks the serum calcium was 11.6, 10, and 10 mg. in three different determinations. With a calcium intake of 0.26 gramme daily for a fortnight the calcium serum figures were 11.2, 10.4, and 9.5 mg.; although during this period the patient had a negative calcium balance, the output being larger than the intake. While there is a noticeable tendency for serum calcium to fall with low and to rise with high calcium intake, it is clear that serum calcium values are to a great extent independent of the intake. Serum calcium values by themselves can hardly be utilized as a criterion of an insufficient calcium intake.

Calcium Balances

In our experiments patients were put for a period of fourteen days on high and low calcium intake, all other factors, including the nitrogen intake, remaining the same so far as possible. Between the two periods the patients were kept for some time on a normal diet. With an intake of 0.247 gramme the total output of calcium (Table II) was 0.415 gramme. It increased under an intake of 0.349 gramme, and still more so under 0.39 gramme intake. It will be seen that although with 0.39 of a gramme intake of calcium in the diet the intake is still less than the output, the latter is in this instance greater than when the calcium intake was 0.247 gramme. The same applies

TABLE II.—Percentage Output of Calcium on Various Intakes

No.	Daily Intake (gm.)	Daily Output			Per-centage of Output in Relation to Intake	Daily N Intake (gm.)	No. of Cases
		Urine	Faeces	Total			
1	0.247	0.292	0.123	0.415	168.2	5	4
2	0.349	0.264	0.165	0.429	124.0	10	6
3	0.390	0.368	0.142	0.510	130.3	10	13
4	0.579	0.338	0.132	0.470	83.0	10	6
5	0.824	0.405	0.154	0.559	68.1	25	8
6	1.791	0.623	0.409	1.032	65.0	10	13
7	1.990	0.315	0.282	0.597	30.0	5	4
8	2.566	0.460	0.371	0.831	35.2	25	8
9	2.712	0.442	0.290	0.732	27.0	25	6

when comparison is made between the first and second series of cases. These figures suggest that when the calcium intake is low the calcium requirement values become reduced, for in the first series of cases an intake of 0.415 gramme would make good the calcium loss, whilst in the second series of cases it would require 0.429 gramme to balance the calcium output.

Starting with the fourth series of cases we find that the calcium output is greater in this series taken as a whole than in the first group of cases; but they differ from all the latter in so far as from now onwards the calcium intake is greater than the output. (The actual output in the fourth series of cases is slightly lower than in the third, but the difference is so slight that it does not really count, considering the large number of cases.)

We are now in a position to consider balances between calcium intake and output, particulars of which will be found in Table II under the heading "Percentage of Output." In the first three series of cases there is a negative balance, the output being greater than the intake. In all others the balance is positive, the intake being greater than the outgoings. There is a depletion of calcium in the first three series of cases and an accumulation of the substance in all the others. We may take it that the calcium intake covering optimum requirements is one with neither a negative nor a positive balance. Looking at Table II, this will be found between a calcium intake of 0.39 and 0.579 gramme. This figure agrees quite well with that of Sherman, Rose, and Rose (1920), who found the minimum calcium requirement to be 0.45 gramme a day for an adult. The minimum calcium requirement is probably lower than the figure given by these authors. In our first series of cases under an intake of 0.247 gramme the calcium output was 0.415 gramme, so that the latter amount would restore the equilibrium between income and expenditure. In our experiments on protein metabolism we found that a low protein intake, which at first resulted in a negative balance, if continued for a long period ultimately established an equilibrium. In this way we have obtained equilibria on very low protein intake. Very likely this applies also to calcium. Our experiments with a low calcium intake, however, did not last longer than two weeks.

Negative Calcium Balance

Calcium metabolism is very complicated, a considerable number of factors coming into play, and some of its features are still awaiting clarification. In the long run the organism cannot put out more calcium than it takes in. Ultimately some sort of equilibrium on a lower level of income will have to be established. In cases in which this does not take place a condition resembling osteomalacia must appear. The bones become soft owing to depletion of the calcium deposits. We do not know whether this condition is met with in England. In any case it is very rare. But, apart from this condition, we may be quite sure that ultimately some balance is estab-

lished between intake and output. One of us has made careful inquiries from a large number of patients attending the Heart Hospital in regard to the diet they are in the habit of taking at home. In no one instance was it found that the average calcium intake was below 0.45 gramme daily. In a good many instances the calcium intake was far above this figure—sometimes four or five times greater. Still more significant is the absence of evidence of any kind that adults (pregnant women excepted) suffer from the effects of calcium insufficiency. Rickets and tetany we may safely leave out of consideration. Sometimes in cases of nephritis the blood calcium tends to be low, but in this instance we may be sure it has nothing to do with an insufficient calcium intake. In some cases of malnutrition a low blood calcium is observable, but in these cases obviously it is not the calcium intake alone which is insufficient. One of us has been looking for years for cases of calcium insufficiency in an extensive hospital practice, and latterly in an institution where normal people are examined periodically, but not one case was found. The dental surgeon of the institution just mentioned makes x-ray examinations of the teeth as routine: he too was unable to draw attention to one case of calcium insufficiency. None of us remembers seeing a pathological specimen from an adult that exhibits a lesion in which calcium deficiency is a factor. Yet we are assured on the authority of no less a person than Sir John Orr that in about half of the population of this country the calcium intake is below requirements. In other words, every second person we meet is a victim of hypocalcaemia. Well, all we can say is that since this type of malnutrition gives rise to so few manifestations it cannot be such an undesirable state to be in.

Positive Calcium Balance

On a high calcium intake there is retention of this substance. We may be sure that the piling of calcium in the body cannot continue *ad infinitum*. With a positive balance the depots of the body are filled to overflowing. But, what is more important, we have definite evidence that in such circumstances tissue calcium is raised, including tissue calcium of the blood vessels. A number of rabbits have been kept by us on a diet rich in calcium, and here are the results of the analyses of two aortas.

	Diet	Calcium of Aorta
Rabbit 1	High calcium	16.2 mg./100 gm.
" 2	"	16.9 "
Control animal	Normal "	9.0 " "

After a certain level of accumulation of calcium is reached an equilibrium must be established between income and output. But the body calcium under such conditions will be higher all round than under a moderate calcium intake. Such is one effect resulting from excess of calcium intake.

Another aspect of high calcium diet is as follows. We have seen that with a high calcium diet calcium is retained; the total output is nevertheless larger under this condition than with a moderate calcium intake. Using the formula of Hill and Bancroft for estimating kidney work, which is

$$A = RT \left[\sum \left(C_{u \log e} \frac{C_u}{C_b} \right) + \sum C_b - \sum C_u \right]$$

where C_u = molar concentration in urine of any constituent,
and C_b = " " " " blood " " "

we found in one case the work of the kidney—expressed as litre atmos./litre—to be 18.8 on a calcium intake which was only moderately high, whilst on a lower calcium intake it was 5.1. In another case on a calcium intake which was moderately high the figure was 14.0, whilst on a lower calcium intake it was 0.9. We found that calcium

comes second only to protein as an important factor in kidney strain. Now it is an established fact (Harris, 1937) that if damaged kidneys are called upon to perform excessive work the blood pressure rises as an adaptation in order to help the kidney to get rid of the products of metabolism. It is evident that every gramme of calcium which is taken unnecessarily will raise the blood pressure in incipient and established cases of hypertony and in turn overstrain the heart, the blood vessels, and the kidney. It must with mathematical accuracy adversely affect the life of the victim.

We know that arteriosclerotic vessels contain more calcium than normal ones. Whether this is simply a secondary effect or whether the condition is helped along by an excessive calcium intake has not been established as yet. It is at present the fashion to disregard diet as a factor in this type of disease; but the above-mentioned findings in the aortas of rabbits fed on diet rich in calcium will take a great deal of explaining away. Long ago it was shown (Jacoby, 1916) that calcium "thickens" the kidney's filter and makes the performance of its function more difficult. According to the Registrar-General's returns, arteriosclerosis is more prevalent among the affluent classes—the people who are in the habit of taking food rich in calcium, and protein too. It is possible that the poorer classes are less prone to this disease because the calcium intake among other types of food is generally lower. It cannot be said that as yet the evidence conclusively establishes a relation between arteriosclerosis and nutrition, but the facts so far ascertained are highly suggestive.

Conclusion

It can be said that there is no particle of evidence which suggests that the vast majority of the population of this country are suffering from the effects of calcium insufficiency. Indeed, with a high degree of certainty it can be affirmed that the calcium intake under the present dietary regime is ample. On the other hand, a considerable amount of evidence exists that large sections of the population are in the habit of using too much of the type of food which is rich in calcium. There may be an indication for reducing the food calcium, but there is none at all for increasing it. Sir John Orr concedes that in half the population the calcium intake is satisfactory. Well, this half will be suffering from the effects of hypercalcaemia if the calcium content in our diet is raised.

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The following medical promotions in and appointments to the Venerable Order of the Hospital of St. John of Jerusalem were announced in the *London Gazette* of January 3: as Commanders (Brothers), Major-General N. M. Wilson, C.I.E., O.B.E., I.M.S., Colonel H. Stott, O.B.E., I.M.S.; as Officers (Brothers), Dr. J. R. S. Park, Colonel W. C. Paton, I.M.S., Dr. W. Steven, Sir C. S. Hicks, M.D., Dr. V. W. T. McGusty, O.B.E., Dr. R. B. MacGregor, Dr. N. Jennings; as Associate Officers (Brothers), Dr. P. Parthasarathy, Colonel P. B. Bharucha, O.B.E., D.S.O., I.M.S.; as Serving Brothers, Dr. W. Hughes, Dr. A. P. Gorham, Dr. J. A. L. Roberts, Dr. H. Mercer, Dr. W. L. Stewart, Dr. H. W. Miller, Dr. S. McClure, Dr. R. A. W. Procter, M.C., Colonel D. C. L. Orton, Dr. T. O'Brien, Dr. H. M. Mills, Dr. J. M. Morris, Dr. C. D. Wilson, Dr. H. H. Warren, Dr. R. R. Scott, C.M.G., M.C., Dr. N. Chilton; as Serving Sisters, Dr. Margaret Joyce, Dr. Elsie C. Hanson, Miss Hilda M. Lazarus, F.R.C.S., Dr. Mabel C. Freeston.