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THE EFFECT OF A LOW-REFINED-CARBOHYDRATE HIGH-PROTEIN DIET UPON NONFASTING BLOOD CALCIUM*

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In an earlier report (1), the findings obtained from a study of the effect of a low-refined-carbohydrate high-protein diet upon non-fasting blood sugar were analysed. This paper will attempt to present the results derived from an analysis of the effects of the same diet upon calcium metabolism.

It is generally recognized that a definite relationship exists between the diet and blood calcium. Brewer *et al.* (2) studied over-weight college women, supplied with various low-carbohydrate diets. The retention of calcium by the subjects was significantly lower than that observed in women of average weight on well-balanced controlled diets (higher carbohydrate intake). Sen and Chaudhury (3) showed from a study on rabbits that intravenously infused glucose increased the blood calcium content. Wesson and Boyle (4) observed that high dietary carbohydrate increases the effectiveness of vitamin D in young rats in assisting in the retention of calcium. Other studies by Bergeim (5) demonstrated that increased (50%) carbohydrate intake results in a distinct increase in calcium absorption while Dupre and Semeonoff (6) showed, under these conditions, a marked rise in the serum calcium. In effect, all these studies on lower animals emphasize that serum calcium rises with an increase in carbohydrate intake.

In all the reports with human subjects, increasing carbohydrate-intake resulted in an elevation in blood calcium content. Parenthetically, of all the carbohydrates studied, lactose exerted this effect most dramatically. Thus, human observations confirm animal studies in that there is a corresponding increase in blood calcium with increase in carbohydrates.

There is agreement among most authors, working both on lower animals and human subjects, that there is a direct relationship (7) between the amount of dietary protein and the blood calcium content. It would, therefore, seem that both protein and carbohydrate levels are positively correlated with serum calcium.

It is generally conceded that a higher calcium intake produces an increase in calcium absorption and retention in man. Jacoby and Dobbs (8) studied two cases of hyper-calcemia in infants and noted that both the patients had normal serum levels after treatment with a low calcium diet. The utilization of calcium tends to be more efficient when the diet is carefully balanced (9). With well-

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balanced intake, the normal range for calcium in 511 boys, aged between 8 and 20 yr. proved to be 8·5 to 10·9 mg. per cent. Nationality and race also showed no influence on the value (10). There is, thus, general agreement that calcium intake and serum calcium parallel each other.

It appears from the available reports that in lower animals a fast of short duration may not change the blood calcium level but it does reduce the same over a long period (11). Jaffe and Bodansky (12) offered the following limits for calcium values (in mg. per cent) after a twelve-hour fast: 9·5 to 10·5 for adults, 10·0 to 11·5 for children, and 10·5 to 12·0 for infants. A difference of one mg. per cent, below the low and above the high values, represents a definite hypo- and hyper-calcemia respectively.

Methods

Four hundred and ninety-three ambulatory Caucasian patients were studied with regard to calcium metabolism as measured by serum calcium (13—16).

Table I shows the age and sex distribution. The subjects were divided almost equally between the male and female groups, the mean ages being 51·8 and 50·6 yr. respectively. The maximum number of patients were between 50 and 69 yr. of age. The age of five out of 493 subjects was not determined and hence they were left out in subgroup analyses.

Each patient attended the clinic between 9 and 12 A.M. after a customary breakfast. A venous sample was drawn and non-fasting serum calcium was determined immediately. The scores obtained will hereafter be referred to as based on a "regular diet."

The patient was then given dietary instructions to follow for the next 3 days. Meat, fish, fowl, vegetables, whole grain (as bread, cereals, vegetables), eggs, nuts, and butter were allowed in quantities desired by the patient. Weak tea, decaffeinated coffee, natural condiments, and water were allowed *ad libitum*. Specific instructions were given to the patient not to take any sugar and refined sugar products, white flour foods, fruit and fruit juices, milk and milk products (except butter), preserved meats, hydrogenated fats and alcohol. The only dietary supplement given for those 3 days was one tablet of 75 mg. of vitamin C (from rose hips) daily. Hereafter, this regimen will be referred to as a "basic or preparatory diet" (preparatory to blood tests). To ensure that the instructions were rigidly followed, the patient was given a form on which all foods taken were to be recorded during this period. However, no quantitative estimation of calcium intake was made.

Finally, the patient was instructed to return on the fourth day at around the same time after breakfast based on the above recommendations. At this second visit, a venous sample was again drawn and a serum calcium was immediately determined.

Results

The findings will be considered in two ways: (i) general characteristics, and (ii) subgroup analyses.

(*i*) *General characteristics*: The mean initial blood calcium for the 493 patients was found to be 9·94 mg. per cent with a standard deviation of 0·72 mg. per cent which means that 68% of the patients had the range from 9·22 to 10·66 mg. per cent. This is quite in accord with postprandial determinations described earlier in this report (12). The mean serum calcium of the patients after three days on the preparatory diet decreased to 9·78 mg. per cent with a standard deviation of the difference of 0·75 mg. per cent.

The scores obtained for the 493 patients initially and after the dietary regimen are represented in Fig. 1. The largest darkened area signifies the group of

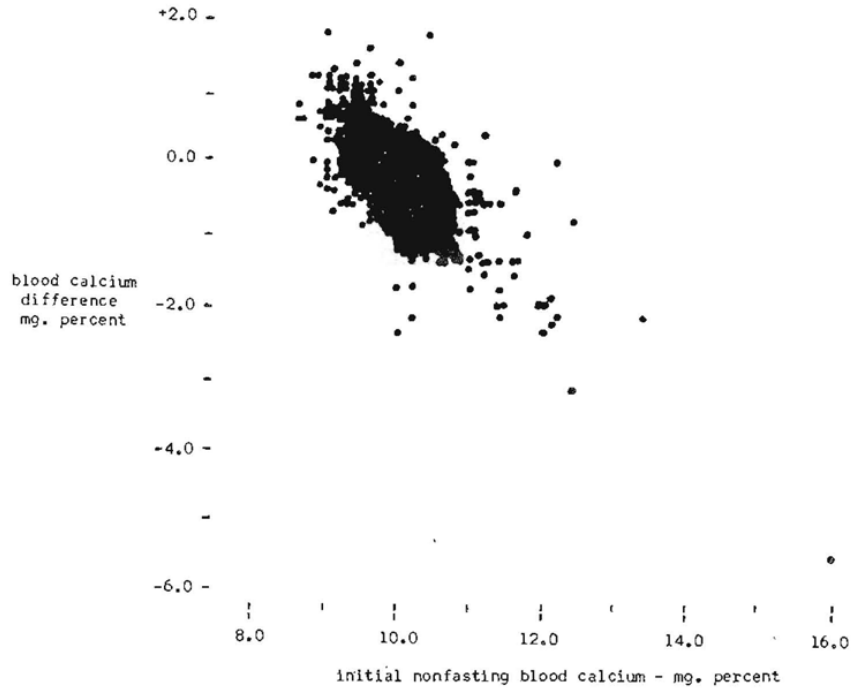

FIG. 1. Comparison of serum calcium before and after a three-day low-refined-carbohydrate high-protein diet

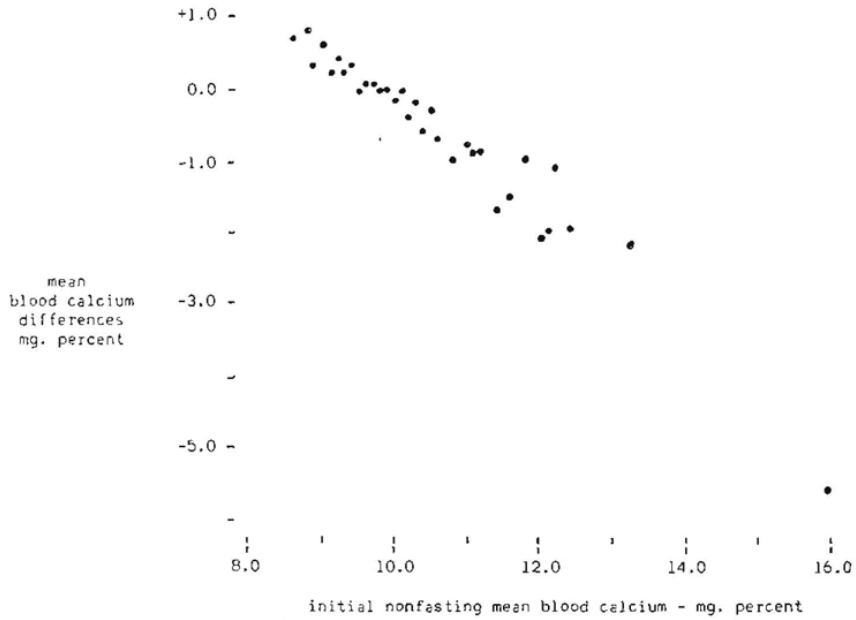

FIG. 2. Comparison of mean serum calcium levels before and after a three-day low-refined-carbohydrate high-protein diet

patients with initial and final non-fasting levels of approximately 9·7 mg. per cent. It is very clear from this graph, and particularly from Fig. 2 showing the mean values, that there is a definite line of regression. The coefficient of correlation was found to be −0·659 and 0·788 for the males and females respectively with a $P < 0.001$. Thus, the evidence reasonably indicates that under this dietary programme, patients' serum calcium, above or below the level, tends to be adjusted to or around 9·7 mg. per cent.

TABLE I

Age and sex distribution

Age group	Male		Female		Total	
	No.	%	No.	%	No.	%
10-29	10	2·02	16	3·24	26	5·26
30-49	89	18·06	83	16·84	172	34·90
50-69	120	24·34	124	25·15	244	49·49
70-89	22	4·47	24	4·87	46	9·34
Undetermined	0	0·00	5	1·01	5	1·01
	241	48·89	252	51·11	493	100·00

TABLE II

Blood calcium changes following a three-day low-refined-carbohydrate high-protein diet

Age and sex groups	Regular diet		Difference after 3 days on exptl. diet		P
	Mean	Standard deviation	Mean	Standard deviation	
10-29 yr.					
Male (10)	10·33	0·89	+0·20	0·42	>0·200
Female (16)	9·74	0·41	+0·04	0·30	>0·200
30-49 yr.					
Male (89)	9·96	0·72	−0·11	0·84	<0·001
Female (83)	10·02	0·91	−0·18	0·84	<0·001
50-69 yr.					
Male (120)	9·84	0·67	−0·20	0·72	<0·001
Female (124)	9·98	0·64	−0·20	0·68	<0·001
70-89 yr.					
Male (22)	10·13	0·69	+0·29	1·03	<0·025
Female (24)	9·72	0·45	+0·01	0·55	<0·005

No. of subjects in parentheses; values expressed as mg. per cent serum calcium.

The question arose as to whether the blood calcium changes would significantly differ if the low-refined-carbohydrate high-protein diet were to be continued for longer than 3 days. To resolve this question, 24 subjects were studied initially (regular diet), 3 days later (basic diet), and several days to weeks later maintaining the same basic dietary regime. Values of $9{\cdot}99 \pm 0{\cdot}61$, $9{\cdot}75 \pm 0{\cdot}55$, and $9{\cdot}73 \pm 0{\cdot}96$ were obtained respectively. Thus, it appears that serum calcium levels continue to approach 9·7 mg. per cent beyond the three day diet period though the major changes developed during the first threedays.

(*ii*) *Subgroup analyses*: The non-fasting serum calcium levels initially and 3 days later in terms of age and sex are shown in Table II. Statistically significant

changes could be observed in the serum calcium level in all but the lowest (10-29 yr.) age groups. A closer examination of the Table II shows that in both the 30-49 and 50-69 yr. age groups the serum calcium tends to approach 9·7 mg. per cent whereas in the oldest age group (70-89 yr.) a tendency towards a higher score was observed.

It may be pointed out that serum calcium in the 493 subjects was determined by the Kramer-Tisdall method (*loc. cit.*). It appeared important to establish whether similar patterns would be derived by other methods. Accordingly, 25 subjects were investigated as previously described except that the serum calcium determinations were done spectrophotometrically (17).

Fig. 3 shows that serum calcium values, above and below approximately 10 mg. per cent following the three-day diet, decreased and increased respectively to or about the same level. Specifically, at the beginning of the study, the serum calcium was found to be $10{\cdot}06 \pm 0{\cdot}30$ mg. per cent. Three days later the mean decreased to 10·04 and the standard deviation came down to 0·25. The statistical significance of the change is underscored by a coefficient of correlation of $-0{\cdot}743$ and $P < 0{\cdot}001$.

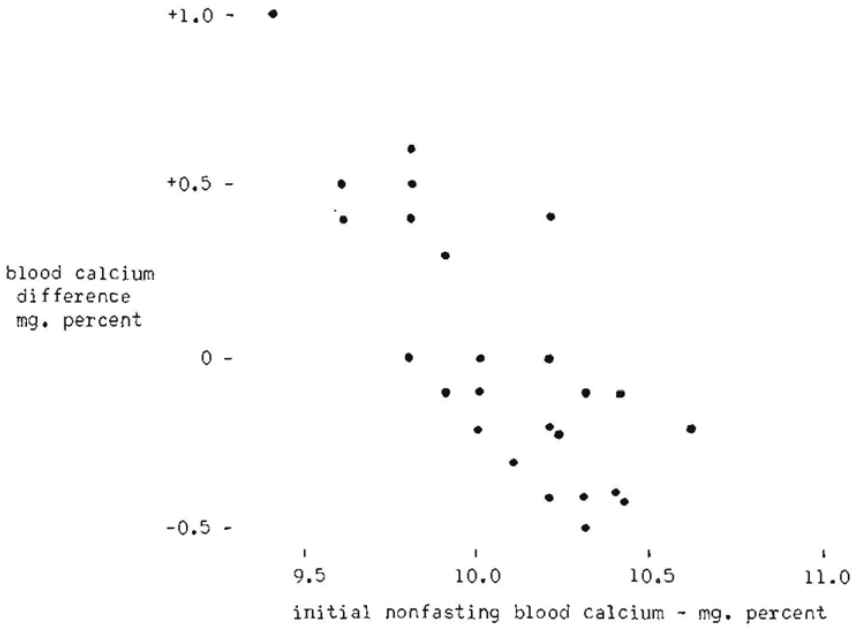

FIG. 3. Comparison of serum calcium before and after a three-day low-refined-carbohydrate high-protein diet (spectrophotometric determinations)

DISCUSSION

The evidence from these 493 subjects indicates that there is a tendency for the non-fasting serum calcium to approach 9·7 mg. per cent under the conditions of a high-protein low-refined-carbohydrate diet. This is underscored by the reduction in the mean, by the very clear-cut line of regression, and the highly significant negative correlation. Although it is not proper to draw conclusions from such data yet the evidence at least suggests that 9·7 mg. per cent might well be the ideal physiologic non-fasting serum calcium.

The most interesting observation from this three-day dietary regimen is that serum calcium levels below 9·7 mg. per cent increased, which has not been previously reported. These results, together with those mentioned above allow the following speculations: (i) protein and carbohydrate (other than refined) contribute measurably to serum calcium homeostasis, and (ii) the delicate hormonal regulation of serum calcium functions more efficiently in a low-refined-carbohydrate high-protein environment.

A study of the sex differences reveals that the non-fasting serum calcium in the female is ordinarily much closer to 9·7 mg. per cent than observed in the male and that with dietotherapy, the female responds with levels closer to this value. It also suggests that the same value may be the physiologic serum calcium point.

The values summarized in this paper indicate that the response to diet is more pronounced with increasing age, possibly because the nutritional imbalance is more serious in the aged. The imbalance might not persist long enough for clear-cut changes in serum calcium in the young. Whether this is the entire explanation or only part of it cannot be concluded from this particular study.

It is noteworthy that the changes in serum calcium under this dietary regimen are similar to the blood sugar and glucose findings previously reported (1). In both instances, the values decreased to within a relatively narrow range indicating the possibility that the physiologic ranges for both blood glucose and serum calcium may be more limited than currently held.

Summary

1. Non-fasting serum calcium analyses of 493 patients were made initially (during a period of regular diet) and 3 days after a high-protein low-refined-carbohydrate regimen.

2. It appears from the results that the changes which occur with this dietary programme become significant with advancing age.

3. It would appear, at least presumptively, that 9·7 mg. per cent (Kramer-Tisdall-Clark method) and 10·0 mg. per cent (spectrophotometric method) may well be the ideal non-fasting serum calcium level.

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