Effect of Deficiency of Magnesium and Other Minerals on Protein Synthesis. (19881)

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A recent study(1) stressed the importance of potassium in protein synthesis. We undertook to determine the importance of magnesium and other mineral elements in this process.

Method. Female albino rats (Wistar) of approximately 200 g were subjected to protein depletion, as in the work of Cannon *et al.*(1), by means of a ration deficient only in protein (2% of total calories, with casein as sole protein source) for 4 weeks. During this period an average of 25% of their initial weight was lost. The animals were then divided into 4 groups of 4 animals each (approximately the same number as used by Cannon) except Group 4, which consisted of 3 animals. All were given a basal ration containing, per 100 g, 9 g casein which had been subjected to hot alcohol extraction (Vitamin-Free Test Casein, from General Biochemicals, Inc.) 75 g cane sugar, 7 g butter, 1 g U.S.P. cod liver oil, 5 g non-nutritive cellulose fiber (General Biochemicals, Inc.) and 3 g aqueous mixture containing 300 mg choline (as the monobasic citrate), 1 mg thiamine hydrochloride, 4 mg niacin, 2 mg riboflavin, 2 mg calcium pantothenate, and 1 mg pyridoxine hydrochloride. The water soluble vitamin content† of this ration was similar to that of Cannon *et al.* (1). The importance of using hot alcohol-extracted casein in a magnesium-deficient ration was originally stressed by Kruse *et al.*(2). Group 1, serving as a control, received a complete mineral supplement, which had the same total of each mineral element as the Hawk-Oser modification of the Osborne-Mendel salt mixture(1). Four g of this mineral supplement was added to each 100 g of basal ration fed to Group 1. Group 2 received an amount of mineral supplement equivalent to that of Group 1 but lacking magnesium; K_2SO_4 and Na_2CO_3 were substituted respectively for $MgSO_4$ and $MgCO_3$ to give the same amounts of SO_4 and CO_3, thus making the total Na and K slightly higher in the salt mixture of Group 2 than of Group 1. The mineral supplement of Group 3 consisted solely of NaCl and KCl (thus lacking Mg, Ca, P, Fe, and trace elements), the total Na and K being equal to these totals in the supplement fed Group 1. Group 4 received no mineral supplement.

Results. (See Table I) Group 1 (complete supplement) had to be restricted in its consumption of the basal ration to keep the intake close to the amount consumed by Group 2 (Mg deficient). Groups 2, 3 and 4 were permitted to eat *ad libitum*. Group 3 (NaCl and KCl) ate less than Group 2 (Mg deficient). On a per rat basis, Group 4 (no salts) ate almost as much as Group 3. Table I shows the total basal ration consumed per rat for each group during the first 10 days on this ration and the mean weight gain per rat for each group (with the standard deviation of the mean) during this period. Group 1 gained the most weight per rat, and each succeeding group gained less than the preceding one on a per rat basis. The differences in mean weight gain per rat between succeeding groups were statistically significant, p being less than 0.01 for the differences between succeeding groups in all instances.

Comments and conclusions. Group 1 (complete supplement) gained over 40% more than Group 2 (Mg-deficient), although Group 1 ate only 4% more than Group 2. Cannon *et al.* (1) found that deficiency of potassium resulted in a decreased rate of protein repletion. Although muscle tissue has less than one-tenth as much magnesium as potassium, deficiency of magnesium was as profoundly deleterious to protein regeneration in these experiments

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† Kindly contributed by Dr. Louis Freedman of U. S. Vitamin Corp., New York.

TABLE I. Effect of Different Mineral Supplements on Weight Gain.

Group	Mineral supplement	No. of rats	Avg consumption of basal ration per rat (g/10 days)	Avg wt gain per rat (g/10 days)
1	Complete	4	112	30.5 ± 2.33
2	Mg-deficient	4	108	21 ± 1.47
3	NaCl and KCl	4	83	15.5 ± 1.04
4	No salts	3	81	11.3 ± .88

as was lack of potassium in the experiments of Cannon *et al.*(1) where the food intakes were kept approximately equal. Group 2 showed no outward anatomical or physiological signs of magnesium deficiency(2) other than decrease in appetite and in weight gain.

Group 2 (Mg-deficient), which ate 30% more than Group 3 (NaCl and KCl), gained over one-third more than the latter, whose salt supplement (NaCl and KCl) resembled that frequently given when protein hydrolysates or amino acids are administered parenterally. If Group 3 (deficient in Mg, Ca, P, Fe, and trace elements) had been forced to eat as much as Group 2 (Mg-deficient), the weight gain per rat of Group 3 would hardly be expected to have exceeded that of Group 2. That is, a complete mineral supplement might here be expected to promote at least 40% more protein regeneration than would a supplement of only KCl and NaCl at the same level of protein and caloric intake.

The food consumption per rat of Group 3 (NaCl and KCl) was only 2% greater than for Group 4 (no salts), but the weight gain per rat of Group 3 was over one-third greater than for Group 4. Hence the supplement of NaCl and KCl apparently exerted its favorable influence on protein regeneration without significantly stimulating appetite.

In these conclusions, as in those of Cannon *et al.*(1), it has been assumed that gain in body weight is essentially a gain in muscle and visceral tissue of normal protein content. However, it should be borne in mind that water storage can affect weight. Thus Group 4 (no mineral supplement) may have gained less weight than Group 3 (NaCl and KCl) partly because Na and Cl are needed for a normal increment of extracellular fluid while K would play a similar role for intracellular fluid. Neither nitrogen balance nor fat deposition was investigated. The effect of the various mineral deficiencies on the absorption of protein from the gut also was not studied in this investigation.

Summary. Controls receiving a complete mineral supplement gained over one-third more weight than rats on a magnesium deficient diet. These, in turn, gained over one-third more than animals receiving only KCl and NaCl as their mineral supplement, while the latter gained about a third more than rats not receiving mineral supplement. The unfavorable effect of magnesium deficiency on the synthesis of protein appears to be approximately as great as that reported for potassium deficiency, although there is far more potassium than magnesium in muscle and viscera.

1. Cannon, P. R., Frazier, L. E., and Hughes, R. H., *Metabolism,* 1952, v1, 49.

2. Kruse, H. D., Orent, E. R., and McCollum, E. V., *J. Biol. Chem.,* 1932, v96, 519.

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