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PUBLICATION OF
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PHOSPHORUS AND MAGNESIUM BALANCE OF ADOLESCENT FEMALES FED TWO LEVELS OF ZINC

J. L. GREGER, J. HUFFMAN, R. P. ABERNATHY, O. A. BENNETT and S. E. RESNECK

ABSTRACT

Utilization of phosphorus and magnesium by 11 girls (12.5–14.2 yr of age) was measured during a 30-day period in which two different levels of zinc (11.5 and 14.7 mg daily) were fed. The former level is similar to that consumed usually by adolescent females; the latter level is similar to the Recommended Dietary Allowance for zinc. Apparent retention of phosphorus was reduced significantly ($p < 0.02$) when subjects were fed the higher level of zinc. Both urinary and fecal phosphorus levels were greater, but not significantly greater, when subjects consumed the higher level of zinc. The variations in dietary zinc levels had no effect on magnesium utilization.

INTRODUCTION

SEVERAL INVESTIGATORS have reported finding Americans who were in poor nutritional status in regard to zinc (Greger, 1977; Hambidge et al., 1972, 1976; Henkin et al., 1974; Pories et al., 1967; Sandstead, 1973). Before programs to increase dietary zinc levels are implemented, the effect of varying dietary zinc levels on the use of other nutrients needs to be studied thoroughly. In animal studies and in vitro preparations, zinc has been demonstrated to be antagonistic to the absorption of other minerals (Magee and Matrone, 1960; Murthy et al., 1974; Van Campen and Scaife, 1967). During severe dietary zinc deficiency, animals have been found to lose excessive amounts of nitrogen in the urine (Hsu and Anthony, 1975). Chu and Cox (1972) observed decreased amounts of phosphorus containing compounds in the tissues of animals fed high levels of zinc. However, the effect of moderate alterations in dietary zinc levels on the utilization of other nutrients by human subjects has received limited attention (Greger et al., 1978a, b, d; Hess et al., 1977; Keltz et al., 1978; Meiners et al., 1977; Tamura et al., 1978).

The purpose of this study was to determine if moderate alterations in dietary zinc levels resulted in changes in the utilization of phosphorus and magnesium by adolescent females.

METHODS

Subjects

Eleven girls, between 12.5 and 14.2 yr of age, agreed to participate in a 30-day metabolic study. Parental approval was also obtained. All subjects were given a routine physical examination by a physician with urine analysis prior to their participation in the study. All procedures used in this investigation were approved by Purdue University's committee on the use of human subjects.

The subjects' mean height was 158 ± 7 (SD) cm; their mean weight was 52.5 ± 13.6 kg. Six of the subjects had already experienced menarche.

Authors Huffman, Abernathy, Bennett and Resneck are with the Foods & Nutrition Dept., Purdue University, West Lafayette, IN 47906. Author Greger, formerly affiliated with Purdue, is now with the Nutritional Sciences Dept., University of Wisconsin-Madison, Madison, WI 53706. All communications concerning this manuscript should be sent to Dr. Greger.

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Experimental design

The subjects were split randomly into two groups. During period 1, the first 14 days of the study, group A was fed 11.3 ± 0.8 mg zinc daily (Diet Z11.5) and group B was fed 14.5 ± 0.8 mg zinc daily (Diet Z14.7). During period 2, the last 16 days of the study, group A was fed 14.8 ± 1.1 mg zinc daily (Diet Z14.7) and group B was fed 11.6 ± 1.1 mg zinc daily (Diet Z11.5). The higher levels of dietary zinc were achieved by adding a zinc sulfate solution (donated by Mericon Industries, Inc., Peoria, IL) to the lemonade served at lunch to subjects.

Experimental diet

A 6-day cycle menu containing foodstuffs typical of adolescent food patterns was served throughout the study. The diet was calculated by computer using U.S. Department of Agriculture food composition tables (Watt and Merrill, 1963) and nutrition information supplied by companies to contain 100% of the Recommended Dietary Allowances (RDA) (Food and Nutrition Board, 1974) for 11–14 yr old girls of energy, protein, vitamins A, B_6, and C, thiamin, riboflavin, niacin, and iron. More details on the diets were given in a previous paper (Greger et al., 1978d).

When similar menus were fed previously, the level of magnesium was found to be low (Greger et al., 1978b). Hence, the girls were given 25 mg of magnesium in the form of magnesium gluconate at each meal. The diet was determined by analysis to contain 1049 ± 50 mg calcium, 906 ± 92 mg phosphorus, 271 ± 22 mg magnesium daily in period 1 and to contain 1058 ± 112 mg calcium, 946 ± 130 mg phosphorus, and 281 ± 26 mg magnesium daily in period 2.

Analyses

Fecal markers of brilliant blue were given to subjects on days 5 and 14 during period 1 and on days 19 and 28 during period 2. Fecal composites for the two periods were prepared accordingly. Acidified urine samples were pooled for each period also. Food was composited on a daily basis.

Food and fecal samples were ashed as described by Osis et al. (1972). The magnesium content of the ashed samples and of urine samples diluted with 0.5% strontium chloride were determined by atomic absorption spectrophotometry. The recovery of magnesium added to three food samples that were processed in this manner ranged from 96–99%. Phosphorus content of ashed fecal and food samples and diluted urine samples were determined spectrophotometrically by a modification of the Fiske and Subbarow procedure (Lindberg and Ernster, 1956). The recovery of phosphorus added to three food samples that were processed in this manner ranged from 93–96%.

Fecal and food composites were analyzed for dry matter content. Duplicate aliquots of the composites were dried in a vacuum oven at 70°C for at least 6 hr and dry matter content of samples were calculated.

All statistical analyses were done by computer utilizing the Statistical Package for the Social Science program (Nie et al., 1975). Paired "t" were used to evaluate differences between treatments (Steel and Torrie, 1960).

RESULTS & DISCUSSION

THE RETENTION of phosphorus by ten of the eleven subjects was less ($p < 0.02$) when the subjects were fed Diet Z14.7 rather than Z11.5 (Table 1). In a previous study with adolescents, we observed no significant effect of dietary zinc levels on phosphorus retention (Greger et al., 1978b). However, in the previous study, the subjects did not serve as their own controls which caused some loss of sensitivity.

The mechanism by which zinc affected phosphorus utilization is unclear. Subjects lost slightly, but not signifi-

Table 1—Phosphorus excretion and retention of adolescent females fed two levels of zinc

Subject no.	Diet Z11.5			Diet Z14.7		
	U[a]	F[b]	R[c]	U	F	R
	(mg/day)					
1	500	508	− 62	580	506	−180
2	329	419	198	430	796	−320
3	535	385	26	583	317	6
4	270	597	79	429	434	43
5	346	660	− 60	430	860	−384
6	377	419	110	408	598	− 60
7	436	462	8	371	600	− 25
8	435	502	29	461	781	−296
9	295	530	81	410	514	22
10	396	402	108	335	590	21
11	382	727	−203	413	674	−141
Mean	393	510	23	441	606	−120
SD[d]	84	111	110	77	164	155

[a] Urinary losses
[b] Fecal losses
[c] Apparent retention = dietary intake − fecal losses − urinary losses
[d] Standard deviation

Table 2—Magnesium excretion and retention of adolescent females fed two levels of zinc

Subject no.	Diet Z11.5			Diet Z14.7		
	U[a]	F[b]	R[c]	U	F	R
	(mg/day)					
1	116	151	11	147	145	−21
2	115	136	30	124	213	−66
3	135	115	31	111	87	73
4	68	172	41	110	114	7
5	129	145	7	147	169	−45
6	110	151	10	113	150	18
7	125	145	1	74	167	40
8	120	152	− 1	94	178	9
9	128	100	43	137	121	23
10	95	183	− 7	96	194	− 9
11	108	163	0	139	151	− 9
Mean	114	147	15	117	157	2
SD[d]	19	24	18	24	34	38

[a] Urinary losses
[b] Fecal losses
[c] Apparent retention = dietary intake − fecal losses − urinary losses
[d] Standard deviation

cantly, more phosphorus in both their urine and feces when fed Diet Z14.7 rather than Diet Z11.5.

Fecal phosphorus losses in this study tended to be somewhat higher than fecal phosphorus levels reported in other studies in which subjects were fed between 800–1000 mg phosphorus daily (Greger et al., 1978b; Leverton et al., 1962; Spencer et al., 1978). There are several possible explanations. The diet contained slightly more calcium than phosphorus. Spencer et al. (1978) observed somewhat increased fecal phosphorus losses as dietary calcium levels were increased. The diet contained the level of nitrogen suggested in the RDA (Food and Nutrition Board, 1974). This is a lower level of protein than adolescent females generally consume (Greger et al., 1978c). Absorption of several minerals is reduced when dietary protein levels are lowered (Schwartz et al., 1973; Walker and Linkswiler, 1972; Van Campen and House, 1974).

The magnesium intake of the subjects in this study was about 90% of the Recommended Dietary allowance for magnesium (1974) and was about 50 mg daily greater than estimated usual intake of adolescent females (Marhefka, 1978). However, two of the girls were in negative magnesium balance when fed Diet Z11.5 and five of the girls were in negative magnesium balance when fed Diet Z14.7 (Table 2). The differences in magnesium excretion and retention due to dietary zinc levels were not statistically significant. Previously, alterations in dietary zinc levels were also not demonstrated to affect magnesium balance significantly (Greger et al., 1978b).

The dry matter content of fecal samples when subjects were fed Diet Z11.5 was 20 ± 4g daily and when subjects were fed Diet Z14.7 was 21 ± 4g daily. While the dietary treatments did not affect the dry matter content of the feces, the dry matter content of fecal samples was correlated to their magnesium content ($r = 0.619$, $p < 0.005$), but not their phosphorus content.

The practical significance of alterations in dietary zinc levels on phosphorus utilization by Americans is unclear. The two levels of zinc fed in this study were representative of the level suggested in the RDA (Diet Z14.7) and of the level consumed by adolescent females (Diet Z11.5) (Greger et al., 1978c). The dietary phosphorus level in this study was about 0.9g daily. Marston and Friend (1966) on the basis of retail weight of food sold in the U.S.A. suggested that Americans consumed 1.5g phosphorus daily. Perhaps if the subjects had consumed a higher level of phosphorus, the majority (7 out of 11) of the subjects would not have been in negative balance in regard to phosphorus when fed Diet Z14.7. Even so, this interaction deserves further study.

REFERENCES

Bell, R.R., Draper, H.H., Tzeng, D.Y.M., Shin, H.K. and Schmidt, G.R. 1977. Physiological responses of human adults to foods containing phosphate additive. J. Nutr. 107: 42.

Chu, R.C. and Cox, D.H. 1972. Zinc, iron, copper, calcium, cytochrome oxidase, and phospholipid in rats of lactating mothers fed excess zinc. Nutr. Rep. Int. 5: 61.

Food and Nutrition Board. 1974. "Recommended Dietary Allowances." 8th rev ed. National Academy of Sciences, Washington, DC.

Greger, J.L. 1977. Dietary intake and nutritional status in regard to zinc of institutionalized aged. J. Geront. 32: 549.

Greger, J.L., Abernathy, R.P. and Bennett, O.A. 1978a. Zinc and nitrogen balance in adolescent females fed varying levels of zinc and soy protein. Am. J. Clin. Nutr. 31: 112.

Greger, J.L., Baligar, P., Abernathy, R.P., Bennett, O.A. and Peterson, T. 1978b. Calcium, magnesium, phosphorus, copper, and manganese balance in adolescent females. Am. J. Clin. Nutr. 31: 117.

Greger, J.L., Higgins, M.M., Abernathy, R.P., Kirksey, A., DeCorso, M.B. and Baligar, P. 1978c. Nutritional status of adolescent girls in regard to zinc, copper, and iron. Am. J. Clin. Nutr. 31: 269.

Greger, J.L., Zaikis, S.C., Abernathy, R.P., Bennett, O.A., and Huffman, J. 1978d. Zinc, nitrogen, copper, iron, and manganese balance in adolescent females fed two levels of zinc. J. Nutr. 108: 1449.

Hambidge, K.M., Hambidge, C., Jacobs, M., and Baum, J.D. 1972. Low levels of zinc in hair, anorexia, poor growth and hypogeusia in children. Pediat. Res. 6: 868.

Hambidge, K.M., Walravens, P.A., Brown, R.M., Webster, J., White, S., Anthony, M. and Roth, M.L. 1976. Zinc nutrition of preschool children in the Denver Head Start program. Am. J. Clin. Nutr. 29: 734.

Henkin, R.I., Schecter, P.J., Raff, M.S., Bonzert, D.A. and Friedewald, W.T. 1974. Zinc and taste acuity: A clinical study including a laser microprobe analysis of the gustatory receptor area: In "Clinical Applications of Zinc Metabolism," Ed. Pories, W.M., Strain, W.R., Hsu, J.M. and Woolsey, R.L., Charles C. Thomas, Springfield, IL.

Hess, F.M., King, J.C. and Margen, S. 1977. Effect of low zinc intake and oral contraceptive agents on nitrogen utilization and clinical findings in young women. J. Nutr. 102: 2219.

Hsu, J.M. and Anthony, W.L. 1975. Effects of zinc deficiency on urinary excretion of nitrogenous compounds and liver amino acid catabolizing enzymes in rats. J. Nutr. 105: 26.

Keltz, F.R., Kies, C., and Fox, H.M. 1978. Urinary ascorbic acid excretion in the human as affected by dietary fiber and zinc. Am. J. Clin. Nutr. 31: 1167.

Leverton, R.M., Leichsenring, J.M., Linkswiler, H., and Meyer, F. 1961. Magnesium requirement of young women receiving controlled intakes. J. Nutr. 74: 33.

Leverton, R.M., Leichsenring, J.M., LInkswiler, H., Fox, H., and Meyer, F.L. 1962. The metabolic response of young women to a standardized diet. Home Economic Research Report No. 16. USDA Washington, DC.

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