MAGNESIUM, CALCIUM AND PHOSPHORUS METABOLISM IN PONIES FED VARYING LEVELS OF MAGNESIUM

H. F. Hintz and H. F. Schryver

Cornell University, Ithaca, New York[1]

Summary

A 3 X 3 latin square design balance trial was conducted with three mature ponies fed diets containing 0.16, 0.31 or 0.86% magnesium. Increasing the dietary level of Mg increased Ca absorption but did not affect P absorption. Increasing the Mg intake increased Mg retention, urinary losses and apparent and true digestibility of magnesium. Estimated endogenous fecal and urinary Mg losses were 2.2 mg and 3.9 mg of Mg/kg of body weight, respectively. The maintenance requirement for ponies was estimated to be 12.8 mg Mg/kg of body weight.

Introduction

The dietary requirements of horses for magnesium, calcium and phosphorus are influenced by the interrelationships among these nutrients. For example, high levels of dietary phosphorus decrease the absorption of calcium (Schryver, Hintz and Craig, 1971a) and magnesium (Hintz and Schryver, 1972). The following trial was conducted to study the effect of various levels of dietary magnesium on magnesium, calcium and phosphorus metabolism in mature ponies when the calcium and phosphorus were present in the diet at levels adequate for maintenance.

Materials and Methods

Magnesium, calcium and phosphorus balances were determined in three mature ponies (avg wt 181 kg) fed diets containing 0.16, 0.31 or 0.86% Mg (table 1). The low level was selected to approximate the maintenance requirement. The design was a 3 X 3 latin square. All diets were pelleted and the ponies were fed 1,360 g twice a day. The ponies were housed in metabolism crates which permitted complete and separate collection of feces and urine. Collection periods were 10 days and were preceded by preliminary periods of at least 3 weeks. Blood samples were taken daily for the last 7 days of each collection period. Calcium and magnesium contents were determined by atomic absorption spectrophotometry and phosphorus was determined by the stannous chloride – hydrazine reduction of phosphomolybdic acid.

TABLE 1. COMPOSITION OF EXPERIMENTAL DIETS

Ingredient	1	2	3
		%	
Timothy hay	10.00	10.00	10.00
Cellulose[a]	25.00	25.00	25.00
Corn	54.50	54.25	53.50
Soybean meal	8.00	8.00	8.00
Molasses	2.00	2.00	2.00
Calcium carbonate	0.50	0.50	0.50
Magnesium oxide	—	0.25	1.00
Magnesium[b]	0.16	0.31	0.86
Calcium[b]	0.62	0.47	0.46
Phosphorous[b]	0.30	0.28	0.27
Protein[b]	9.03	8.83	8.88

[a]Solka-Floc, Brown Paper Co., Berlin, New Hampshire.
[b]90% dry matter basis.

Results

Although the diets were formulated to contain similar levels of all nutrients except Mg, the low Mg diet contained a higher level of Ca according to analyses. Perhaps there was an error when weighing the calcium carbonate. Consequently, the Ca intake was greater when the low magnesium diet was fed (table 2). However, the estimated true digestibility of Ca was greater for the high Mg diet and hence, there were no significant differences in Ca retention between the low Mg and high Mg diets. The levels of Mg in the diets did not significantly affect any of the P values studied. Increasing the Mg intake significantly increased fecal and urinary Mg excretion and Mg retention. Apparent digestibility and estimated true digestibility of Mg were greater for the two diets containing the higher levels of magnesium.

The equation $Y = -6.15 + 0.48X$ (figure 1) describes the relationship of Mg retention (Y) to Mg intake (X) ($r = 0.960$) and predicts zero Mg retention when intake is 12.8 mg/kg of body weight per day. The equation also predicts an endogenous loss of -6.15 mg/kg of

[1]The authors wish to acknowledge the assistance of J. Cooper, P. Daniluk, S. Hallett, C. Marquis, K. O'Neil and J. Williams.

TABLE 2. CALCIUM, PHOSPHORUS AND MAGNESIUM BALANCES

Magnesium level	Intake	Feces	Urine	Retained	Apparent digestibility	Est. true[a] digestibility
%	- - mg/kg of body weight - -				%	%
			Calcium			
0.16	92.0[b]	52.2[b]	10.4	29.4[b]	43.3[b]	65.0[b]
0.31	62.7[c]	37.5[c]	8.1	17.1[c]	40.2[b]	72.1[b,c]
0.86	65.0[c]	29.9[c]	9.5	25.6[b]	54.0[c]	84.8[c]
$S_{\bar{x}}$	2.3	1.5	1.0	3.9	2.4	2.3
			Phosphorus			
0.16	43.2	35.4	N.D.[h]	7.8	17.9	41.2
0.31	36.6	30.4	N.D.	6.2	16.9	44.3
0.86	35.2	29.8	N.D.	5.4	15.3	43.7
$S_{\bar{x}}$	1.8	1.5		1.0	2.0	1.9
			Magnesium			
0.16	23.7[e]	12.6[e]	5.6[b]	5.5[b]	46.8[b]	53.3[b]
0.31	46.1[f]	19.3[e]	10.7[c]	16.1[c]	58.1[c]	62.5[c]
0.86	131.6[g]	54.0[f]	20.5[d]	57.1[d]	58.8[c]	60.5[c]
$S_{\bar{x}}$	2.5	2.5	1.0	1.3	1.5	1.2

[a]Estimated assuming endogenous fecal excretion of 20 mg Ca, 10 mg P and 2 mg Mg/kg of body weight (Schryver et al. 1970; Schryver et al. 1971b; Hintz and Schryver, 1972).
[b,c,d]Values with unlike superscripts significantly different (P<0.5).
[e,f,g]Values with unlike superscripts significantly different (P<.01).
[h]None detected.

body weight when Mg intake is zero. The equation Y = 2.22 + 0.39 X (figure 2) describes the relationship of fecal Mg (Y) to Mg intake (X) (r = 0.75). Thus, the endogenous fecal Mg loss is estimated to be 2.22 mg Mg/kg body wt/day. Endogenous urinary excretion is estimated to be 3.93 mg/kg body wt/day. The equation is Y = 3.93 + 0.12 X (r = 0.94), where Y = urinary Mg excretion and X = Mg intake (figure 2).

The dietary Mg content did not influence Ca or P serum levels. However, increasing the level of Mg in diet increased the Mg serum levels (table 3).

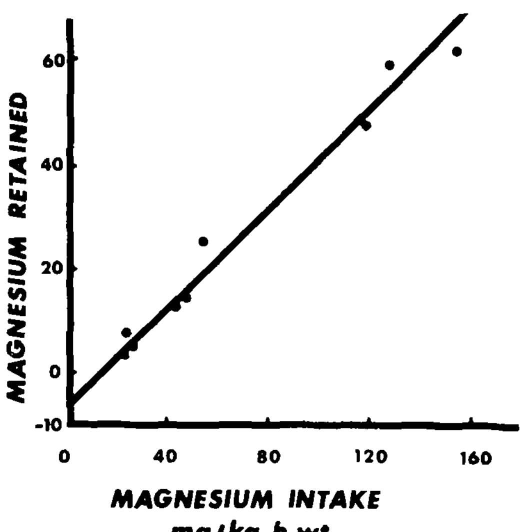

Figure 1. The relationship of magnesium intake to magnesium retention.

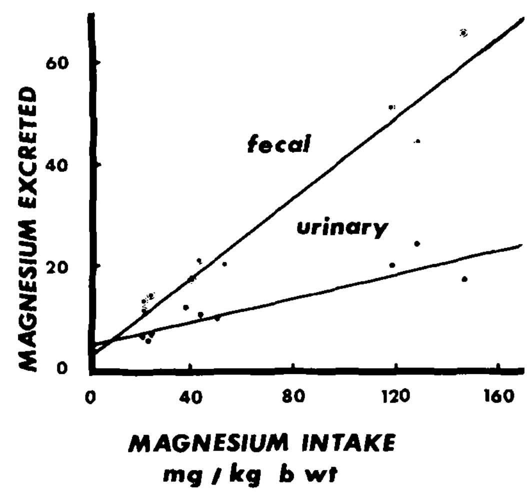

Figure 1. The relationship of magnesium intake to magnesium urinary and fecal exretion.

TABLE 3. EFFECT OF DIETARY MAGNESIUM CONTENT ON MAGNESIUM, CALCIUM, AND PHOSPHORUS SERUM LEVELS[a]

Dietary Mg	Ca	P	Mg
%	mg/100 ml	mg/100 ml	mg/100 ml
0.16	11.91 ± 0.95	3.87 ± 0.43	2.21[b] ± 0.15
0.31	12.08 ± 1.04	4.08 ± 0.44	2.62[c] ± 0.33
0.86	12.00 ± 0.79	3.87 ± 0.67	3.39[d] ± 0.45

[a]Each mean is average of 21 values.
bcd,Values with unlike superscripts significantly different. (P<.05).

Discussion

An increased absorption of Ca due to increased dietary levels of Mg has been reported in rats (Clark, 1968), man (Heston and Parsons, 1961; Briscoe and Ragan, 1966) and calves (Huffman and Duncan, 1935), although other reports indicated Mg decreased Ca absorption or had no effect (Hjerpe, 1968). The reason for the increased absorption is not known and the situation seems quite complex as Mg deficiency also enhances Ca absorption (Alcock and MacIntyre, 1962). Thus, there appears to be a biphasic response of Ca absorption to Mg intake. That is, either Mg deficiency or high levels of Mg may increase Ca absorption.

Although supplemental P decreased Mg absorption in an earlier trial with ponies (Hintz and Schryver, 1972), increased Mg did not influence P metabolism in the present study. Clark (1968) reported that Mg increased P absorption in rats only when the Ca:P ratio was low and suggested the effects of Mg on P absorption that he observed were the result of a Mg – Ca interraction. In our earlier trial (Hintz and Schryver, 1972) the Ca:P ratio for the diet with depressed Mg absorption was 1.0:3.3, whereas, in the control diet and in the diets in the present study, the Ca:P ratio was about 1.0:0.5.

Although high dietary levels of Ca or P could presumably induce a Mg deficiency (Whitlock *et al.*, 1970; Hintz and Schryver, 1972) it does not appear that a high dietary level of Mg would induce Ca or P deficiency in ponies due to decreased absorption of these minerals.

Increasing the Mg level from 0.16 to 0.31% increased the apparent and estimated true digestibility of Mg, with no significant difference between the 0.31% and 0.86% level. However, some of this increase may have been due to the fact that in the basal diet, the Mg was supplied by the feedstuffs while in the other diets, much of the Mg was supplied by MgO, which is probably more available than Mg in feeds. The higher level of Ca in the basal diet may have also decreased the absorption of magnesium or perhaps the decreased absorption was a result of the Ca:Mg ratio. It was 3.9:1 for the low Mg diet and 1.3:1 and 0.4:1 for the diets with higher levels of Mg. The P:Mg ratio may also be important.

Nevertheless, it is obvious that Mg absorption is different from Ca absorption in the horse in that increasing the intake of Ca decreases Ca digestibility (Schryver, Craig and Hintz, 1970).

The estimate of 2.2 mg of endogenous fecal Mg/kg of body weight/day is similar to the 1.8 mg reported for ponies earlier (Hintz and Schryver, 1972), and to the values of 2.3 mg/kg and 2.2 mg/kg reported for sheep (Chicco *et al.*, 1972) and calves (Smith, 1959). The value of 3.9 mg Mg for endogenous urinary excretion is somewhat higher than the 2.8 mg previously reported for ponies (Hintz and Schryver, 1972) but the data again demonstrate that the endogenous urinary loss of Mg is greater than the endogenous fecal Mg loss. The increased urinary excretion of Mg with increased Mg intake demonstrates that the kidney is important in Mg homeostasis.

The estimate that an intake of 12.8 mg Mg/kg of body weight is required/kg of body weight to maintain zero balance in ponies agrees closely with our earlier estimate of 13.1 mg (Hintz and Schryver, 1972).

Literature Cited

Alcock, N. and I. MacIntyre. 1962. Inter-relation of calcium and magnesium absorption. Clin. Sci. 22:185.

Briscoe, A. M. and C. Ragan. 1966. Effect of magnesium in calcium metabolism in man. Amer. J. Clin. Nutr. 19:295.

Chicco, C. F., C. B. Ammerman, W. G. Hillis and L. R. Arrington. 1972. Utilization of dietary magnesium by sheep. Amer. J. Physiol. 222:1469.

Clark, I. 1968. Effect of magnesium ions on calcium and phosphorus metabolism. Amer. J. Physiol. 214:348.

Heston, F. W. and F. M. Parsons. 1961. The metabolic effect of high magnesium intake. Clin. Sci. 21:273.
Hintz, H. F. and H. F. Schryver. 1972. Magnesium metabolism in the horse. J. Anim. Sci. 35:755.
Hjerpe, C. A. 1968. Influence of dietary magnesium on metabolism of calcium and magnesium in sheep. Amer. J. Vet. Res. 29:143.
Huffman, C. F. and C. W. Duncan. 1935. Vitamin D studies in cattle. J. Dairy Sci. 18:605.
Schryver, H. F., P. H. Craig and H. F. Hintz. 1970. Calcium metabolism in ponies fed varying levels of calcium. J. Nutr. 100:955.
Schryver, H. F., H. F. Hintz and P. H. Craig. 1971a. Calcium metabolism in ponies fed a high phosphorus diet. J. Nutr. 101:259.
Schryver, H. F., H. F. Hintz and P. H. Craig. 1971b. Phosphorus metabolism in ponies fed varying levels of phosphorus. J. Nutr. 101:1257.
Smith, R. H. 1959. Calcium and magnesium metabolism in calves. Biochem. J. 71:306.
Whitlock, R. H., H. F. Schryver, L. Krook, H. F. Hintz and P. H. Craig 1970. Effects of high dietary calcium in horses. Proc. 16th Annu. Conf. Amer. Ass. Equine Practitioners. p. 127.