Phosphorus and Selenium Depletion in Thoroughbred Mares and Weanlings

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Summary

Phosphorus, calcium and selenium in blood, urine and diet in 3 feeding groups (on pasture supplemented with hay [PH]; on pasture + hay + concentrate [PHC]; hay + concentrate [HC]) of totally 45 mares were compared. PH and PHC mares had corresponding PH and PHC foals. The diets of PH mares and weanlings were marginal or low in phosphorus and selenium. Whole blood Se reflected dietary Se in mares in weanlings. Plasma P, urine P and (partly) fractional P excretion were highest in the PH mares, but not in PH weanlings (plasma P). The paradoxical hyperphosphaturia was accompanied by a calciuria, especially in the group of PH mares, suggested mobilization of calcium and phosphorus from bone during pregnancy that was exacerbated by low dietary P.

Phosphor- und Selendepletion bei Vollblutstuten und Absatzfohlen

In 3 Fütterungsgruppen (Weide + Heuergänzung [PH]; Weide + Heu + Kraftfutter [PCH]; Heu + Kraftfutter [HC]) mit insgesamt 45 Stuten wurden P-, Ca- und Se-Gehalte in Blut, Harn und Futter verglichen. Die Fohlen der PH- und PHC-Stuten wurden entsprechend als PH- bzw. PHC-Fohlen gefüttert. Die Rationen der PH-Stuten und -Fohlen wiesen marginale oder niedrige P- und Se-Gehalte auf. Die Blut-Se-Konzentrationen der Stuten und Absatzfohlen spiegelten die Se-Aufnahmen über das Futter wider. Die höchsten P-Werte in Plasma und Harn, teilweise auch die höchste P-Clearance (als Anteil der Creatininclearance) wurden bei den PH-Stuten, jedoch nicht bei den Fohlen (Plasma-P) ermittelt. Die paradoxe Hyperphosphaturie war von einer hohen renalen Ca-Exkretion – insbesondere bei den PH-Stuten – begleitet. Somit deutet sich eine Ca- und P-Mobilisation aus dem Skelett während der Trächtigkeit an, die durch niedrige P-Gehalte in der Ration forciert wird.

Introduction

Observations on the mineral status of mares and foals have been made in the course of a study which was concerned primarily with the influence of beta-carotene and vitamin A on reproductive efficiency and growth (described in a companion paper). Interest also focussed on selenium and phosphorus. Pasture contents of selenium form an unpredictable mosaic in Virginia and much of the northeastern quadrant of the USA. Phosphorus usually declines in pastures during late summer and through the winter. Additional observations were made on calcium which interacts strongly with phosphorus in the horse.

Methods

In January 1990, 38 mares were put on mixed grass-clover pastures and divided into 2 groups, one supplemented with mixed grass hay (PH), the other with mixed grass hay and a special concentrate (PHC). The mares foaled from January to June; the foals were weaned in September, 1991 and remained under the same regimens as their dams. Free access was allowed to water and trace mineral salt without selenium for all horses.

In April, 1991, 4 mares without 1991 foals from each group plus another 7 new mares were placed on a drylot. They formed a third group fed the special concentrate and 2-yr. old mixed grass hay (HC). By August 1, all breeding had taken place and 11 mares in both PHC and HC groups and 13 mares in the PH group were pregnant.

Samples of pastures (June and November, 1991), hays and concentrate were subjected to proximate and mineral analysis in the DHIA Forage Testing Laboratory. Blood serum and urine (mares only) were analyzed for calcium, phosphorus, selenium and other substances not reported here.

Beginning December 12, 1991, the PH mares and weanlings were supplied with monoammonium phosphate : trace mineral salt 1 : 1 free choice. Little was consumed. After 3 weeks, dried molasses was added 1 : 1 : 1, and this mixture was consumed at an average rate of 47 g/d/mare but only 5 g/d/weanling, equivalent to 3.76 and 0.4 g/d of phosphorus for mares and weanlings respectively.

Results and Discussion

Feed Analysis

Calcium found was abundant in the concentrate (0.77 % DM) and mixed alfalfa-timothy hay (0.71 %) fed to the weanlings. Calcium in the pastures varied from 0.28 – 0.59 % in June to 0.45 – 0.6 % in November. Grass hay fed to the drylot mares (HC) also varied from 0.28 – 0.55 % while the grass-alfalfa round bales fed to the PH and PHC mares ranged from 0.44 – 0.71 %. Phosphorus was abundant in the concentrate (0.75 % DM) but low in hays (0.14 – 0.32 %) and pastures (0.24 – 0.28 %). Selenium was abundant in the concentrate (6 mg/kg) but low in all pastures and hays (< 0.08 mg/kg). In effect, the PH groups of mares and weanlings were fed diets marginal or low in phosphorus and selenium.

Blood Analysis

Whole blood selenium concentrations are shown in Table 1. In both November 1991 and January 1992, selenium levels were lower in weanlings than in mares. It also was lower in the PH than in the PHC and HC groups of mares. Similarly, it was lower in the PH than the PHC weanlings.

These blood data reflected the low selenium contents of the pastures and hays. Moreover, these findings demonstrated the effectiveness of selenium supplementation by means of the special concentrate.

An unplanned epidemic of mild pneumonia with purulent nasal discharge affected all of the 11 PH weanlings from

Table 1: Whole blood selenium concentrations (ppb,)

	Mares			Weanlings	
	PH	PHC	HC	PH	PHC
November 14, 1991					
Mean	153^{a}	258^{b}	278^{c}	91^{d}	217^{e}
SE	6.4	3.9	5.9	4.6	5.3
January 14, 1991					
Mean	128^{f}	245^{g}	245^{h}	91^{i}	221^{j}
SE	4.0	3.8	6.8	4.0	7.0

$^{a,b}p<0.00000001$; $^{a,c}p<0.00000001$; $^{b,c}p = 0.096$;
$^{d,e}p<0.00000001$; $^{f,g}p<0.00000001$; $^{f,h}p<0.00000001$;
$^{i,j}p<0.00000001$; $^{a,f}p = 0.00045$; $^{b,g}p = 0.056$; $^{c,h}p = 0.00024$.

early October through early December; 2 of the 11 were treated with trimethoprim-sulfadiazine in November. The PHC weanlings were not affected until mid-late December and all but 2 were recovered by mid-January; none were treated.

Blood samples from the weanlings were taken for IgG assay, and IgG along with whole blood and serum selenium concentration will be monitored during selenium repletion, which began in March. IgG has been shown previously to reflect selenium status in horses.

Phosphorus data are shown in Table 2. In weanlings, serum phosphorus concentration was lower in the PH group that in the PHC group in November. This difference reflected the phosphorus contents of feeds and showed the adequacy of supplementation by the special concentrate. However, in January, serum phosphorus levels were not different between groups, with both groups lower than PH in November. The PH weanlings were being offered a trace mineral salt (TMS) with phosphorus beginning 4 weeks before the January blood sample was taken, but this was apparently inadequate.

In the pregnant mares, serum and urine phosphorus was highest in the PH group in November and January (Table 2). Serum phosphorus decreased significantly in the PHC group from November to January. Urine phosphorus increased from November to January in all three groups.

The fractional excretion of phosphorus (FEP) was also higher in the PH group than in the PHC and HC groups in November (Table 2). In January, however, FEP was unchanged in the PH group but had increased significantly in the other 2 groups.

These data show that serum phosphorus concentrations reflected phosphorus contents of feeds and the adequacy of phosphorus supplementation by means of the concentrate in the weanlings but not, paradoxically, the pregnant mares. In November, the high FEP and high serum phosphorus concentration were in apparent conflict with marginal-low dietary phosphorus. From November to January there was no change in serum phosphorus and FEP in the PH group despite phospate supplementation, although the urine phosphate did increase.

Table 2: Serum and urine phosphorus concentration (mg/dl), fractional excretion of phosphorus (FEP, %)

		Mares			Weanlings	
		PH	PHC	HC	PH	PHC
November 14, 1991						
Serum P	Mean	3.54^{a}	3.49^{b}	3.10^{c}	5.71^{d}	6.45^{e}
	SE	0.14	0.14	0.17	0.10	0.12
Urine P	Mean	1.98^{f}	$1,57^{g}$	1.89^{h}		
	SE	0.13	0.09	0.09		
FEP	Mean	0.65^{i}	$0,46^{j}$	0.55^{k}		
	SE	0.11	0.04	0.07		
January 14, 1991						
Serum P	Mean	3.40^{l}	$2,94^{m}$	2.99^{n}	5.17^{o}	5.15^{p}
	SE	0.11	0.10	0.11	0.11	0.11
Urine P	Mean	2.72^{q}	$2,50^{r}$	2.18^{s}		
	SE	0.11	0.11	0.08		
FEP	Mean	0.64^{t}	$0,74^{u}$	0.71^{v}		
	SE	0.045	0.037	0.058		

$^{a,c}p = 0.062$; $^{b,c}p = 0.1$; $^{d,e}p = 0.0001$; $^{f,g}p = 0.015$; $^{g,h}p = 0.021$;
$^{i,j}p = 0.0018$; $^{l,m}p = 0.0063$; $^{l,n}p = 0.016$; $^{q,s}p = 0.0062$;
$^{r,s}p = 0.023$; $^{t,u}p = 0.082$; $^{b,m}p = 0.0012$; $^{d,o}p = 0.00074$;
$^{e,p}p = 0.000008$; $^{f,q}p = 0.001$; $^{g,r}p = 0.000012$; $^{h,s}p = 0.041$;
$^{j,u}p = 0.000005$; $^{k,v}p = 0.037$.

Table 3: Serum and urine calcium concentration (mg/dl), fractional excretion of calcium (FECa, %)

		Mares			Weanlings	
		PH	PHC	HC	PH	PHC
November 14, 1991						
Serum Ca	Mean	13.05^{a}	13.51^{b}	13.10^{c}	12.25^{d}	12.45^{e}
	SE	0.22	0.15	0.26	0.18	0.25
Urine Ca	Mean	209.6	152.0	84.4^{f}		
	SE	46.9	31.6	16.6		
FECa	Mean	18.28^{g}	11.03^{h}	5.28^{i}		
January 14, 1991						
Serum Ca	Mean	13.45^{j}	13.23^{k}	12.40^{l}	11.61^{m}	11.75^{n}
	SE	0.21	0.14	0.19	0.24	0.42
Urine Ca	Mean	323.2^{o}	177.9^{p}	43.4^{q}		
	SE	47.9	27.3	3.1		
FECa	Mean	18.33^{r}	11.13^{s}	4.17^{t}		
	SE	2.61	1.64	0.29		

$^{a,b}p = 0.095$; $^{g,h}p = 0.11$; $^{g,i}p = 0.0032$; $^{h,i}p = 0.037$; $^{j,k}p = 0.0015$;
$^{k,l}p = 0.0022$; $^{o,p}p = 0.016$; $^{o,q}p = 0.000007$; $^{p,q}p = 0.00008$;
$^{r,s}p = 0.051$; $^{r,t}p = 0.00001$; $^{s,t}p = 0.00004$; $^{a,j}p = 0.061$;
$^{c,i}p = 0.037$; $^{d,m}p = 0.031$; $^{e,n}p = 0.069$; $^{f,q}p = 0.026$; $^{i,t} = 0.034$.

Taken on their own, the data on serum phosphorus might suggest that pregnant mares, unlike rapidly growing weanlings, adapted well to the marginal phosphorus diet. The phosphaturia in the PH mares might be regarded as paradoxical, in view of the marginal phosphorus diet and the increasing requirement for pregnancy. An explanation is not obvious, based only on the phosphorus data, but one is suggested by consideration of the calcium and phosphorus data together.

Calcium data are shown in Table 3. In the pregnant mares, serum calcium concentration was higher in the PHC group than in the PH or HC groups in November. In January, however, serum calcium was higher in the PH group than in the HC with PHC in between. From November to January there was a significant change in serum calcium in both PH and HC groups but not PHC.

Urine calcium was highest in PH and lowest in HC both in November and January (Table 3). Urine calcium concentration was unusually high in the PH group (323 mg/dl) in January and there were significant differences between all groups. Only the HC group had a significant change in urine calcium from November to January.

The fractional excretion of calcium (FECa) was highest in the PH group and lowest in the HC group in November (Table 3). Again, there were significant differences between all groups. But only the HC group showed a significant change in FECa from November to January. This coincides also with the feeding of hay lower in calcium (0.30 % DM) in January than in November (0.55 % DM).

If serum calcium concentration remains constant, urine calcium must be accounted for from 2 sources, absorption from the gut and resorption from bone. Calcium absorption might have been greater in the PH group because calcium bioavailability might have been diminished by phytate-phosphorus in the concentrate fed to the PHC and HC groups.

On the other hand, a high rate of bone resorption in the PH mares could account for several observations – the higher serum concentrations of calcium and phosphorus, the higher urine concentrations of calcium and phosphorus, the higher FECa in November and January, and the higher FEP in November.

A high rate of bone resorption would ensure an abundance of calcium and phosphorus for the fetus, in the face of marginal-low dietary phosphorus. It could be mediated by parathyroid hormone. Thus the parathyroid status of pregnant mares receiving a diet marginal-low in phosphorus requires further study.

Conclusions

Blood analysis was consistent with depletion of selenium in mares and weanlings, and with phosphorus depletion in weanlings. It may have been misleading in regard to the phosphorus status of pregnant mares kept on an all-forage diet.

Supplementation with a pelleted concentrate proved to be effective for selenium in mares and weanlings. The concentrate provided adequate phosphorus for weanlings consuming primarily pasture as forage (through November) but perhaps not when consuming primarily hay as forage (January).

Paradoxical phosphatemia and phosphaturia of pregnant mares fed an all-forage diet of pasture and hay, which was marginal or low in phosphorus, remains in question. Our current hypothesis is that phosphorus may have been mobilized from bone, as an adaptation to pregnancy, and ensured a sufficiency of phosphorus for the fetus. At the same time, the elevated serum phosphorus concentration may have resulted incidentally in a greater urinary loss of phosphorus that placed the mare at greater risk of phosphorus depletion. Supplementation with phosphorus tended to diminish the paradoxical phosphatemia and phosphaturia, but further studies in progress are needed to confirm this effect.

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